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MODEL 650
SWEEP OSCILLATOR
plug-in units

USING STEWART BWO TUBES
WITH GRID LEVELING

6578 385

ALFRED ELECTRONICS 3176 PORTER DRIVE, PALO ALTO, CALIF.

INSTRUCTION MANUAL

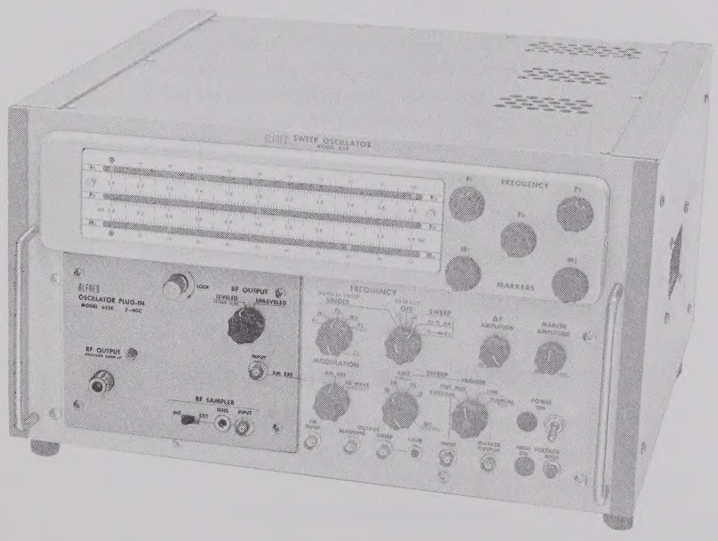
MODEL 650
SWEEP OSCILLATOR

plug-in units

USING STEWART BWO TUBES
WITH GRID LEVELING

6578 (Model) 385 (Serial)

☐ Grid leveled, internal sampling
☒ Grid leveled, external sampling



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ALFRED ELECTRONICS • STANFORD INDUSTRIAL PARK • PALO ALTO, CALIFORNIA
TELEPHONE: 326-6496 (415) • TWX: 910-373-1765

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Table 1-1. Specifications of Grid-Leveled Oscillator Plug-In Units

NOTE: This manual applies to Grid-Leveled Plug-In Units having Stewart/Watkins-Johnson BWO tubes.

Frequency GHz	650 Plug-In Model No.[t]	Power Output (mw)[yy]	Tube Manufacturer	ALFRED Tube No.	Power Variation Leveled db[tt]	Residual FM (Max. KHz.)	Diode Shaper PC Board	Sampler[y]	Sampler Attenuator	Low Pass Filter
1 to 2	651 651K	80 70	Stewart	112-029	±0.3	30	950636	951099	1151[x]	256-6[y]
1.4 to 2.5	651-S1 651K-S1	80 70	Stewart	112-034	±0.3	30	950637	950781	1151-1[x]	
1.7 to 4.2	652-S5 652K-S5	35 30	Stewart	112-033	±0.5	30	950858	950908		256-9[y]
2 to 4	652 652K	70 60	Stewart Watkins-Johnson	112-031 112-095	±0.3	30	950638 951877	951100	1152[x]	256-2[y]
3.5 to 6.75	653-S1 653K-S1	40 30	Stewart	112-035	±0.4	50	950640	950783	1153-1[x]	256-4[y]
3.7 to 8.3	653-S2 653K-S2	10 10	Stewart	112-028	±0.5	50	950965	950896		256-8[y]
4 to 8	653 653K	40 25	Stewart Watkins-Johnson	112-027 112-105	±0.5	50	950639 951909	950784	1153[x]	256-1[y]
7 to 11	654 654K	35 25	Watkins-Johnson	112-039	±0.5	75	951699	951101		256-5[y]
7 to 12.4	654-S1 654K-S1	35 25	Watkins-Johnson	112-039	±0.75	75	951603	951101		256-5[y]
8 to 12.4	655 655K	75 50	Watkins-Johnson	112-038	xx	75	951604	950786		256-5[y]
12.4 to 18	657 657K	40 25	Watkins-Johnson	112-109	±0.8	150 200	951910	950892	950815*	
18 to 26.5	658	20	Watkins-Johnson	112-110		200	951911		950868*	
26.5 to 40	659	>5	Watkins-Johnson	112-111		350	951912		950867*	

* Flap attenuator.
x For external use with Model 650 only.
xx ±0.5 (8.2 to 12.4 GHz); ±0.7 (8.0 to 12.4 GHz).
t K suffix indicates rf leveling sampler mounted internally. Basic model requires an external sampler for leveling.
tt Level variation limits shown for units with internal leveler-sampler can be achieved with at-the-load leveling in all units, by use of a suitable external sampler.
y Used only on units (with K suffix) having internal sampling.
yy Upper figure indicates rated maximum unleveled output from units without internal sampling; lower figure indicates rated maximum leveled output from units with internal sampling.

PULSE MODULATION VOLTAGE REQUIRED AT AM EXT JACK: The pulse modulation voltage required for external on-off modulation varies with the response speed required. A signal of +10V will turn the rf output on with a rise and fall time of about 1 μs in all units, in the unleveled mode. For high-speed, ac-coupled pulse modulation in the unleveled mode with rise and fall time of ≈ 0.1 μs, a pulse amplitude of typically +45 volts with 50 Ω source impedance is required in all units having Stewart (or Watkins-Johnson) BWO tubes. During leveled operation, a signal of +10 V will turn the rf output on with a rise time of about 20 μs in units having grid leveling.

Specifications subject to change without notice. Data not shown was unavailable at press time.

SECTION 1

GENERAL INFORMATION

1.1 SCOPE OF MANUAL.

This manual covers the group of Oscillator Plug-in units of the ALFRED Model 650 Series using Stewart or Watkins-Johnson BWO tubes with grid leveling. All standard plug-in units covered by this manual are listed in Table 1-1.

Table 1-1 also includes performance information pertinent to each plug-in unit, and identifies the components which constitute the main differences between each plug-in unit of the group. These are the backward-wave oscillator (BWO) tube, the diode shaper board which matches the high voltage cathode supply output to the tube characteristic, the rf output low-pass filter, and the internal sampler for K-suffix plug-in units. These component differences are required for operation in the different frequency bands shown in Table 1-1.

This manual should be used as a supplement to the basic Model 650 Instruction Manual. That manual includes all necessary information for operating the Model 650 with any plug-in unit installed. This plug-in unit manual gives supplemental descriptive, theory, and maintenance information pertinent to the plug-in units using Stewart BWO tubes with grid-leveling.

1.2 DESCRIPTION OF PLUG-IN UNIT.

Each plug-in unit is a modular rf head assembly designed to operate with the ALFRED Model 650 to constitute a microwave sweep oscillator. All plug-in units can be operated interchangeably in any Model 650, and no adjustments are required, either on the Model 650 or the plug-in unit, when interchanging plug-in units. Thus, by using several plug-in units interchangeably, a versatile, wide-range oscillator capability is provided at minimum expense, and operation can be extended into additional bands when desired by purchasing additional plug-in units.

The plug-in units using Stewart or W-J BWO tubes with grid leveling, covered in this manual, operate in frequency bands from 1.0 GHz to 40 GHz as listed in Table 1-1. Other plug-in units are available covering frequencies from 0.25 GHz to 40 GHz (see Table 1-2 in the Model 650 manual). All plug-in units are equipped with an internal leveler-amplifier, and can provide leveled rf output when used with an external sampler. Those plug-in units with model numbers having a "K" suffix are also equipped with an internal sampler to permit self-contained leveling. These units have a front panel RF SAMPLER INT-EXT switch to select either internal or external sampling.

The plug-in unit chassis is fabricated from aluminum to avoid interference with the magnetic field of the BWO tube, and the top and bottom panels of the plug-in unit completely enclose the tube for shielding and mechanical protection. The tube is mounted on a center plate in the forward portion of the chassis. The leveler-amplifier and diode shaper plug-in PC boards are located in the rear compartment of the chassis.

The frequency dial plate corresponding to the rf output band of each plug-in unit is stored in the top storage compartment of that plug-in unit, as shown in Figure 2-1 of the Model 650 Instruction Manual. Installation of this plate onto the dial plate area of the Model 650 calibrates the Model 650 for operation with the corresponding plug-in unit.

1.3 OTHER DOCUMENTATION FURNISHED WITH MANUAL.

An envelope at the rear of this manual contains factory performance-test data for the instrument and the BWO tube, as follows:

a. "ADDENDUM A" listing instrument model and serial number of the instrument and the particular values of factory-selected components used; and also listing the tube parameters pertinent to the tube originally shipped in the instrument.

b. A maximum power output performance plot of the plug-in unit made during final swept-frequency testing at ALFRED.

c. For units with internal leveling (K suffix models) a plot similar to b but showing performance in the leveled condition.

SECTION 2

INITIAL INSTRUCTIONS

2.1 GENERAL. Refer to Section 2 of the Model 650 Instruction Manual.

CAUTION

The BWO tube housing contains a strong permanent magnet. This magnet will attract magnetic materials brought near it, and the tube may be damaged (1) by being struck by such materials, and (2) by permanent alteration of its magnetic field by being exposed to such materials. Use only non-magnetic screwdrivers and other tools when working around the plug-in, and remove your wrist watch to avoid magnetic damage to it. The plug-in unit should be kept at least six inches from magnetic materials.

When a plug-in unit is removed from the Model 650, or if a unit is received separately, store it in a suitable shielding container, such as the ALFRED Model 9000 Storage Container, or on wood and at least six inches from magnetic sources.

SECTION 3

OPERATING INSTRUCTIONS

Refer to Section 3 of the Model 650 Instruction Manual.

3.1 REMOVAL, INSTALLATION, AND INTERCHANGING OF PLUG-IN UNITS IN THE MODEL 650.

CAUTION

When changing Plug-in units, turn the POWER switch off and wait 15 seconds before removing the installed Plug-in unit and inserting the other Plug-in unit, to permit decay of the power supply voltages. Then carry out the standard turn-on procedure.

3.1.1 REMOVAL OF A PLUG-IN UNIT FROM THE MODEL 650. To remove a plug-in unit from the Model 650, release its panel LOCK knob by turning fully CCW, and then pull the unit out of the Model 650 by pulling on the LOCK knob. Remove the frequency dial plate for that plug-in unit from the Model 650 panel and attach to the underside of the storage compartment door in the top of the plug-in unit, using the knurled screws removed with the plate. (See Figure 2-1 of the Model 650 Instruction Manual.)

3.1.2 INSTALLATION OF A PLUG-IN UNIT IN THE MODEL 650. To install a plug-in unit in the Model 650, first remove the frequency dial plate from the storage compartment door of that plug-in unit and install it into the calibrated position on the Model 650 panel. (See Paragraph 2.6 and Figures 2-1 and 3-1 of the Model 650 Instruction Manual.) Make sure the plug-in unit LOCK knob is turned fully CCW so the lock arm will clear the Model 650 panel opening and will enter far enough to actuate the safety interlock switch. Then insert the plug-in unit through the Model 650 panel and lock in position by pressing in on the LOCK knob and turning it fully CW.

3.1.3 INTERCHANGING PLUG-IN UNITS IN THE MODEL 650. To interchange plug-in units, follow the procedure of Paragraphs 3.1.1 and 3.1.2 above. The Model 650 is properly calibrated for operation with the new plug-in unit by installation of the frequency dial plate for that unit. No adjustments are required.

3.2 FUNCTIONS OF PANEL CONTROLS, INDICATOR, AND CONNECTORS.

See Tables 3-1 and 3-2 of the Model 650 Instruction Manual. Controls and connectors on the plug-in unit are covered at the end of each table.

3.3 FUNCTION OF TIME METER

The time meter, visible when the storage compartment door is open, is provided as an aid in monitoring the rated number of heater hours of the BWO tube. A mercury line in the meter capillary tube moves from the "0" to the "1" position linearly during a preset number of hours of heater operation, in accordance with the value of factory-selected resistor R11 (normally 2500 hours). The rated number of heater hours for the BWO tubes used in plug-in units covered by this manual is indicated in the Tube Warranty and Replacement Procedure sheet included at the back of this manual. Do not replace the BWO tube just because the time meter has moved full scale. Tube performance rather than time meter indication should be the criteria for tube replacement. Refer to Paragraph 5.4.1 for analysis of BWO tube failure indications.

3.4 OPERATING PROCEDURES

Section 3 of the Model 650 Instruction Manual includes detailed instructions for operation of the plug-in unit and its controls. See paragraph 3.12 of that manual for a discussion of operation with leveled rf output and use of the POWER LEVEL controls.

NOTE: When external leveling is desired on units without internal sampling, it may be necessary to add a low-pass filter externally, between the RF OUTPUT jack and the external sampler, to avoid ripples in the leveled output near the upper end of the band. Units with an internal sampler contain a built-in low pass filter which eliminates the need for an external filter when external leveling is used.

SECTION 4

CIRCUIT DESCRIPTION

4.1 BLOCK DIAGRAM DESCRIPTION

A basic block diagram of the plug-in unit is included in Figure 4-1 (Sheet 2) of the Model 650 Instruction Manual, and the basic functions of the plug-in unit and its three PC Cards (A11, A12, and A13) are described in that manual, in Paragraph 4.1 and Table 4-1.

The backward-wave oscillator (BWO) tube located in the plug-in unit supplies the sweep oscillator rf output. By applying proper drive signals to the BWO tube, the plug-in unit converts the dc power and control signals supplied by the Model 650 chassis into proper-frequency rf output signals with the required modulation and/or leveling. Power supply outputs from the Model 650 are standardized for all plug-in units where possible; but because of the different cathode and anode biasing requirements of different-frequency BWO tubes, the level-controlling feedback for these two supplies is developed in the plug-in units.

The cathode supply voltage applied to the BWO tube controls the rf output frequency. The cathode supply output line passes through the Elevated Supply PC Board A12, where it is connected to the 0-line. It then connects directly to the BWO tube cathode. The cathode supply output varies from -150 V to -2500 V, as required to develop sufficient feedback through the diode shaper board to exactly cancel the linear 0 to +15 V frequency-determining control signal developed by the dc control circuits in the Model 650. The Diode Shaper PC Board A13 is shown in Figure 4-1 (Sheet 1) of the Model 650 Instruction Manual.

The diode shaper board monitors the instantaneous output of the cathode supply through a string of feedback dropping resistors. These resistors drop the voltage value monitored to a range below -15 V, commensurate with the low-voltage control signals. This board then processes the low-voltage monitoring signal to develop non-linear feedback which corresponds to the non-linear cathode voltage-vs-output frequency performance curve of each BWO tube. This arrangement permits linear frequency control with a linear dial and linear control voltages.

The BWO tube helix operates at near-ground potential, being connected to ground through 10 ohms (A12R2 in parallel with A7R14), as shown in Figure 4-10 of the Model 650 Instruction Manual. The BWO tube collector is tied to the +100 V supply through 10-ohm resistor A12R13 in the elevated supply.

The anode supply output line is coupled to the BWO tube through the elevated supply, as shown in Figure 4-11 of the Model 650 Instruction Manual. The elevated supply develops feedback across A12R11, A12R14 to control the anode supply voltage to the level required by each tube. A12R14 is factory-selected, and A12R9 is factory-adjusted to set the proper voltage.

The grid voltage applied to the BWO tube controls the rf output level. The grid voltage is developed by the circuit of A12Q1, as shown in Figure 4-16 of the Model 650 Instruction Manual. This circuit operates within the range of $V_{cathode}$ and -100 V below $V_{cathode}$. The transfer oscillator supplies zero current drive when no modulation or leveling signal is present. This cuts off Q1, bringing the grid close to cathode potential for full rf output power. In this condition, the only drop across L1 and R5 is that due to grid current.

To turn off the rf output during the "off" half-cycle of square wave modulation or during the "rf off" mode, the transfer oscillator generates a current of about 35 ma which develops a drop of 27 V across R5 so that the effective grid-cathode bias of the BWO tube is -27 V. This is sufficient to completely cut off the electron beam in the tube, providing an infinite on-off ratio.

For control of output level in the leveled mode, the tube rf output is reduced during the sweep by a variable amount as required to produce constant power equal to that available at the point of minimum unleveled output. The transfer oscillator generates an analog current drive signal related to the amount of level reduction required, ranging from 0 to less than 35 ma. Transistor Q1 then biases the BWO tube grid as necessary to reduce power to the required steady level.

The Leveler-Amplifier PC Board A11 generates the level-correction control signal for the transfer oscillator in leveled operation. It receives a fixed-level reference signal from the modulator, and a signal proportional to the instantaneous output level from the internal or external sampler. The reference signal level from the modulator can be adjusted by the POWER LEVEL control to achieve balance with the sampler signal at the desired rf power level. The reference signal drops to zero, when modulation is simultaneously applied to the BWO tube, to prevent the leveler from attempting to correct for such desired modulation.

Whenever the reference and crystal detector signals do not cancel, the differential input stage of the leveler-amplifier generates a correction signal which is amplified and applied to the transfer oscillator. The transfer oscillator, in turn, drives Q1 in the elevated supply as described above. The sensitivity of the feedback-stabilized leveler-amplifier is high enough that it holds the rf output level within a fraction of a db regardless of the unleveled characteristic of the tube. As the output sweeps through frequencies where the unleveled characteristic is several db higher than the minimum-power point in the band, the leveler increases the correction signals in response to the increased crystal output, and prevents the level from increasing more than about 0.3 db.

Whenever power is leveled over the full range being swept, a variable-level positive signal is continually supplied to the transfer oscillator.

When such a positive output signal is continuously supplied, it also drives an amplifier stage to cut off power from the UNLEVELED WHEN LIT light. The absence of a positive leveler

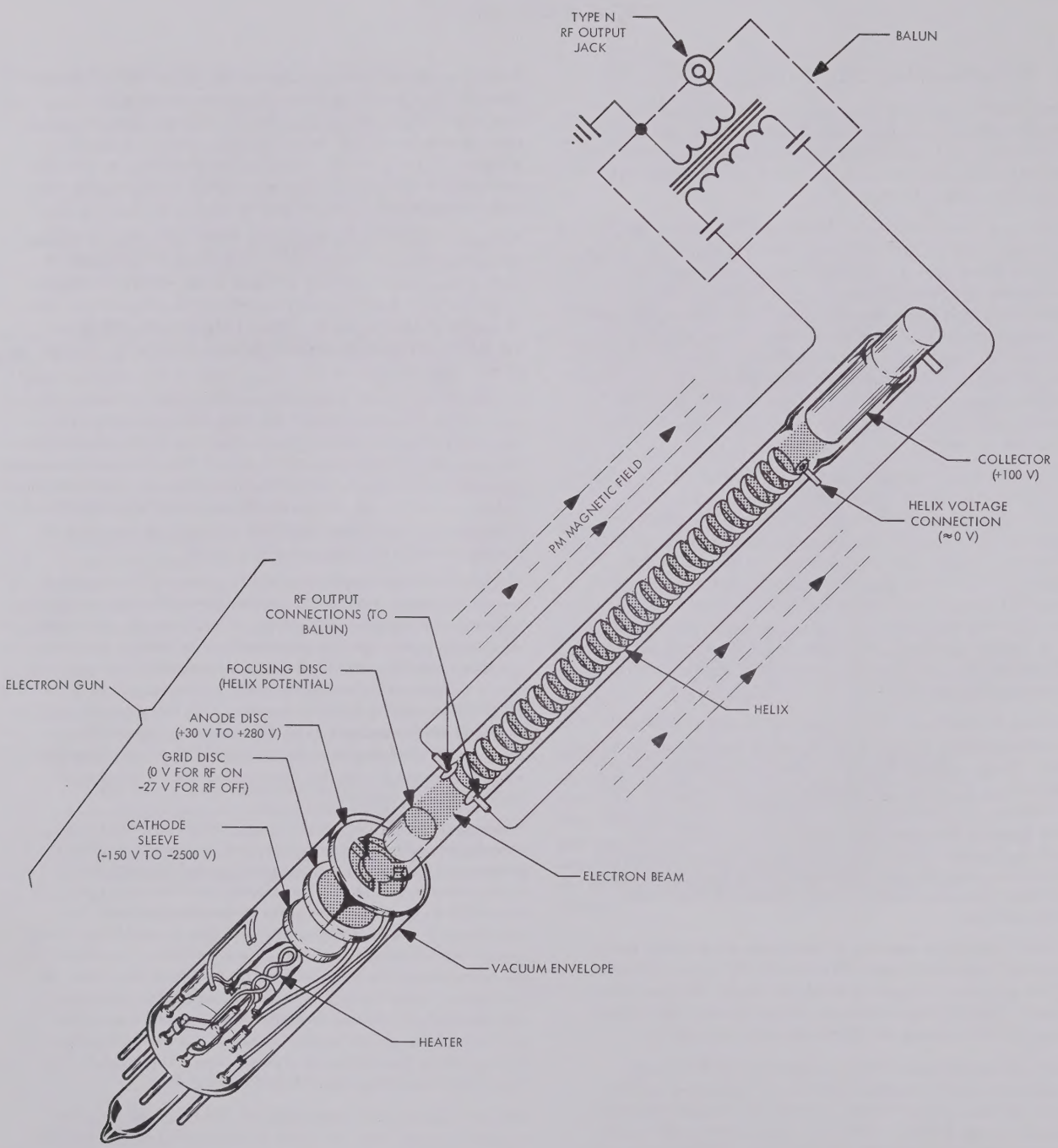
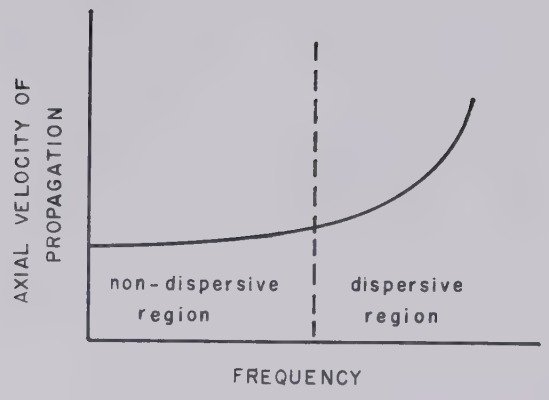
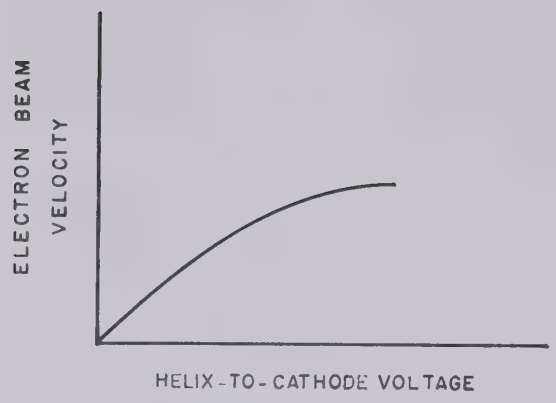


FIGURE 4-1. BACKWARD WAVE OSCILLATOR TUBE



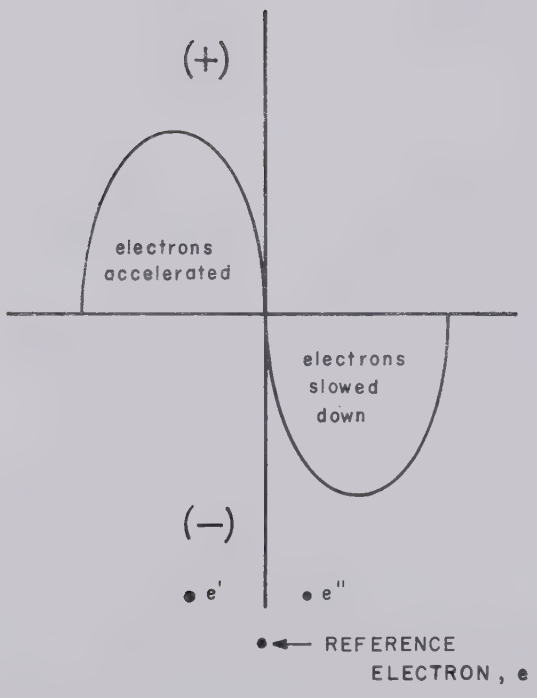
AXIAL VELOCITY OF PROPAGATION VS. FREQUENCY

(A)



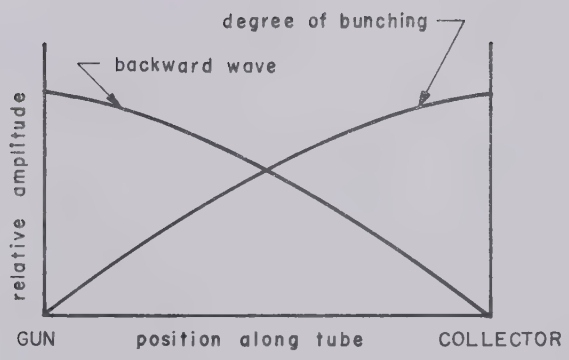
ELECTRON BEAM VELOCITY VS. HELIX-TO-CATHODE VOLTAGE

(B)



ELECTRON DISTRIBUTION

(C)



RELATIVE AMPLITUDE VS. POSITION ALONG TUBE

(D)

FIGURE 4-2. OPERATING CHARACTERISTICS OF BWO TUBE

output signal during any portion of the band, indicating that the output signal is totally or partially unleveled, is sufficient to allow the UNLEVELED light to glow.

The signal level applied to the leveler-amplifier from the internal or external detectors is adjustable with individual SENSITIVITY controls to provide optimum response in the leveled loop.

4.2 THE BACKWARD WAVE OSCILLATOR TUBE (See Figure 4-1.)

The backward-wave oscillator (BWO) tube is a voltage-tunable microwave oscillator vacuum tube. It consists of an electron gun, a slow wave structure (helix), and a collector at the far end of the slow wave structure. The rf output of the tube is produced by the interaction between the electron beam passing from the gun to the collector and the electromagnetic field of a microwave signal developed on the slow wave structure.
Surrounding the evacuated envelope of the tube is a cylindrical permanent magnet which produces a strong axial field. This field focuses the electrons in the beam and allows movement only in the direction of the axis of the tube.

An exterior housing completely covers the magnet and tube, and no magnet adjustments are possible. The tube electrodes are connected to wire leads which are brought out through the housing for connection to the Elevated Supply PC Board A12 of the plug-in unit. The electron gun contains a heated cathode and two or more operature disc type control electrodes (grid and anode) which help form the beam and control beam density. In a helix backward wave oscillator, it is desirable to have a hollow cylindrical electron beam since only the electrons that pass adjacent to the helix are fully effective in delivering energy to the wave. Electrons near the middle of the beam consume anode power but contribute little or nothing to the energy interchange that produces the backward wave oscillations. The electron gun elements are arranged to generate a hollow, circular electron beam. The magnetic field, which restricts the electrons to axial movement, then maintains the same geometry to achieve a hollow cylindrical beam throughout the length of the slow-wave structure.

The helix is a slow-wave structure equal in length to several wavelengths of the lowest output frequency. Thus, the operating frequency range of a particular backward wave oscillator tube is primarily determined by the dimensions of the helix.

It is well known that a slow wave structure will propagate a particular range of frequencies at constant axial velocity (the non-dispersive region) and above that range, the axial velocity of propagation increases with frequency (the dispersive region). The backward wave oscillator operates in the dispersive region and it will oscillate at the frequency for which the electron beam velocity is very nearly equal to the axial velocity of propagation of the microwave signal on the helix. Figure 4-2A shows the variation of propagation velocity with frequency for a particular helix while Figure 4-2B shows how the beam velocity varies with the helix to cathode voltage.

From these figures it can be seen why the backward wave oscillator can be voltage tuned. By changing the helix to cathode voltage, the electron beam velocity changes, thereby changing the frequency for which the velocity of propagation on the helix and the velocity of the beam are in synchronism. The helix dimensions, primarily diameter and pitch, are chosen so that the tuning voltages required for a particular frequency range are reasonable (usually about 200 to 2000 volts).

The oscillations, and hence the rf wave, begin in the backward wave oscillator in much the same manner as they begin in other oscillators. Noise waves are established on the helix from the shot noise coupled from the electron beam and from thermal energy developed at the input end of the tube. Rf waves are produced which travel in both directions in the helix, i.e., from gun to collector and from collector to gun. Since the desired wave in a backward wave oscillator must travel from the collector to the gun end, attenuators are placed in the tube which eliminate the forward-moving waves. Amplification of the rf wave is produced by the interaction of the electrons in the beam and the electromagnetic field of the wave.

To obtain this interaction, the electron beam must be at some critical velocity which is achieved by applying a dc voltage to the helix. Because the rf electromagnetic field is alternating, electrons in the beam are subjected to either an accelerating or decelerating field. Thus, the beam electrons passing axially near the helix experience velocity modulation, with a tendency for bunches of electrons to be formed as the beam moves through the helix. The critical areas of interaction are adjacent to the spaces between the helix turns because the axial electric field is strong between helix turns and weak under the turns.

To explain the bunching process let us examine a group of electrons as they travel from the gun to the collector end of the tube. Within this group there will be one electron, e, which corresponds to the zero point of the alternating axial field and is therefore unaffected by the signal on the helix. See Figure 4-2C. This electron experiences no acceleration from the electromagnetic field. However, electron e', just to the left of e, encounters a positive axial field and is accelerated, thus tending to catch up with e. Similarly, electron e", which is just to the right of e, encounters a negative or decelerating field and so slows down and tends to be overtaken by electron e.

The electrons centered about e are thus velocity modulated. This situation is repeated over and over again as the electrons centered about the reference electron pass one space after another enroute from the gun to the collector.

If the helix-to-cathode voltage is set to achieve a beam velocity such that at the collector end of the tube the phase difference between the wave and bunches in the beam is approximately one half cycle, the electron bunches will encounter relatively strong decelerating fields as they cross the spaces. Thus, the kinetic energy of the electrons is transferred to the backward wave. The amplitude of the backward wave builds up as it progresses toward the gun end of the tube because it passes more and more bunches from which it receives energy. At the same time, the alternating component of the beam current, i.e., the bunching, becomes greater as the electrons progress toward the collector, because of the continuing velocity-modulation interaction between the beam and the established backward wave. See Figure 4-2D.

The rf output signal generated on the helix is coupled off the helix at the gun end on two insulated wires which terminate in an external balun. The balun contains capacitors which block the dc operating potential and allow the output type N connector to operate at chassis ground. These two wires are connected to the end loop of the helix at points 180° apart, to provide balanced output. The required cathode-to-helix operating potential is obtained by operating the helix near chassis ground and the cathode below ground. To shift the operating frequency from the low to high band limits, an exponential change of cathode supply voltage over a range of about 7:1 is required. The diode shaper board A13 is factory-

set to provide the proper tuning voltage range for each tube, within the supply limits of -150 V to -2500 V.

The anode is operated at a positive potential with respect to the cathode, and the elevated supply board A12 is factory-set to provide feedback that develops the required output within the supply limits of +30 V to +280 V. The grid is operated at cathode potential for full rf output power, and at -27 V to cut off the electron beam, thereby turning off the rf output completely. The grid provides a non-linear control range between these limits, which is useful for power leveling control by means of a closed-loop feedback system.

Typical cathode current is less than 30 milliamperes, and it divides between the helix and collector. The collector is operated at above-ground potential through a resistor from the +100 V supply, and thus is 100 V positive with respect to the helix. Helix, collector and anode operating currents are critical operating parameters and must not exceed the power dissipating capability of the tube elements. Operating current limits for these currents on the particular tube installed in each plug-in unit are indicated on the tube data sheets enclosed in the envelope bound into the rear of this manual. Because of variations in optimum operating currents and distribution of currents between electrodes in BWO tubes of the same type, the rf power output characteristics should be used as the principal indicator of tube performance.

The rf power output is proportional to the beam current. Beam current is controlled by both grid bias and anode voltage, and maximum beam current is limited by the power dissipating capacity of the helix and anode. Since variations in anode voltage also affects the frequency of oscillation, the sweep oscillator operates with constant anode voltage, and grid bias is used to control power output.

In the "standby" mode when the FREQUENCY Mode Selector switch is turned OFF, the heater, cathode, anode, collector, and helix voltages are maintained, and the grid is biased to cut off the beam. With the other voltages applied, the tube is continuously being outgassed, and it has been found that through this technique, tube life is extended by more than 10%.

4.3 TUBE PERFORMANCE MONITORING. Cathode, heater, and anode supply voltages are monitored by means of TP6 through TP9 on the Model 650 chassis, which connect to the supply outputs in that unit. Grid voltage, which is developed in the active stage of the elevated supply PC Board A12 in the plug-in unit, is monitored by TP23 on the left side of the plug-in unit.

Helix current is coupled to terminal 19 of the elevated supply, through the normally-closed contact of FREQ STABILIZING INPUT connector J5. This current is shunted to ground through A12R2, a 12.5-ohm resistor in the elevated supply in parallel with A7R14, a 49.9-ohm resistor in the helix overcurrent protection circuit (see Figure 4-10 of the Model 650 Instruction Manual). The helix current divides between the two resistors in about a 4:1 ratio, so that a total of 5 ma helix current is required to produce 1 ma across A7R14 which trips the helix overcurrent relay. The voltage produced by the helix current flow through these resistors is monitored at TP22. The monitored voltage will be 10 mv/helix ma, and will be less than 50 mv, which corresponds to the tripout level.

Collector current is coupled to the +100 V supply through a 10-ohm resistor. TP21 is tied directly to the collector, so that the voltage developed by the collector current passing through the resistor will cause the voltage at TP21 to drop from +100V (TP1) by 10 mv/collector ma.

4.4 FREQUENCY STABILIZING INPUT.

The FREQUENCY STABILIZING INPUT jack J5 provides a means of applying feedback to the helix to alter the instantaneous helix-to-cathode voltage in single-frequency operation. When generated by a suitable discriminator, such feedback can stabilize the rf single-frequency output to an accuracy approaching that of the best cavity-tuned microwave oscillators. When a mating connector is inserted in J5, it opens the normally-closed contacts shunting R15, so that the applied stabilizing feedback voltage is developed across R15, in series with the helix-to-ground voltage produced by the helix current flow through A12R2 and A7R14. When external stabilization is used, the discriminator voltage applied across R15 ranges between 0 and ±50 V. A positive voltage tends to increase the axial velocity of propagation of the electron beam by reducing the voltage differential between the anode and helix. This tends to increase the oscillation frequency, in accordance with Figure 4-2A. Conversely, a negative voltage tends to decrease the beam velocity and output frequency. The response characteristics are mainly determined by the external feedback discriminator used to generate the stabilizing signal. The discriminator must have a low output impedance in order to supply the required helix current without affecting the voltage stabilization action.

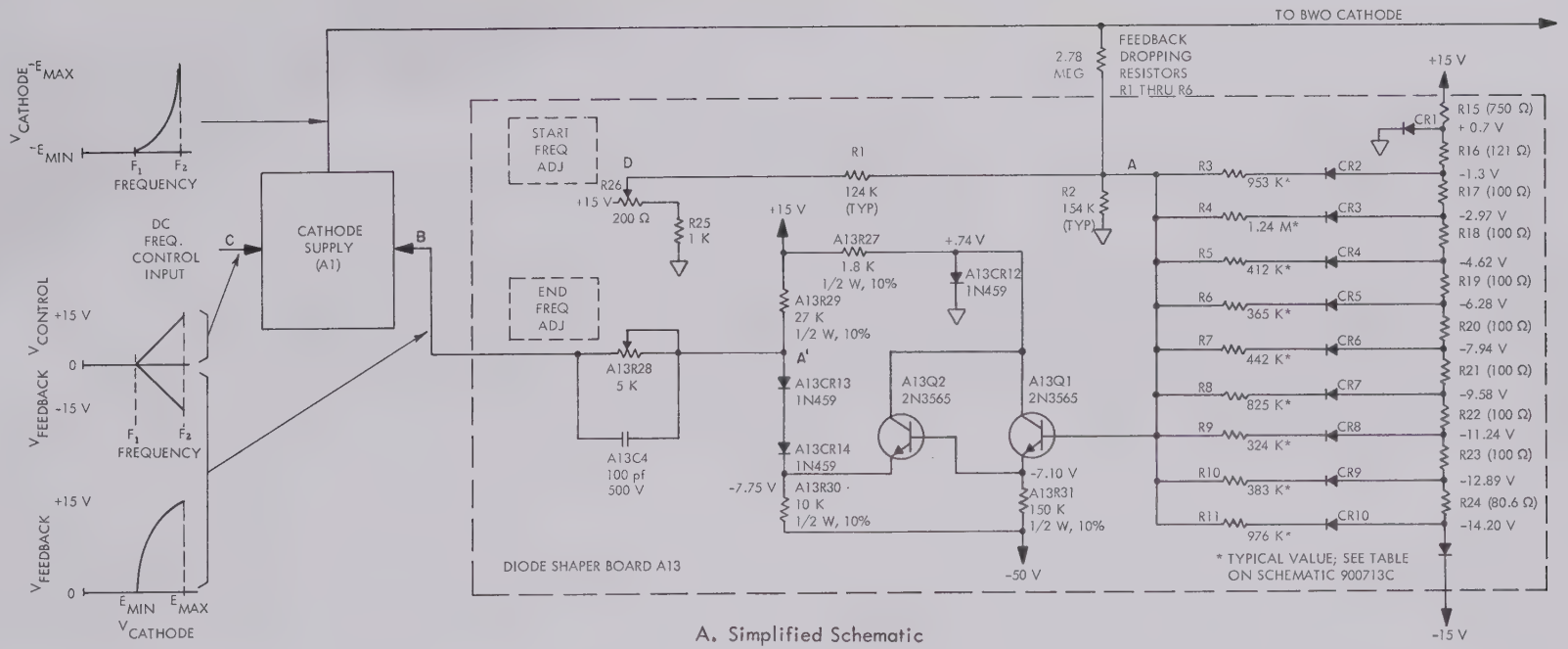
4.5 DIODE SHAPER BOARD (see Figure 4-3).

The diode shaper board provides non-linear feedback as required to produce a tube electron beam velocity which yields frequency output that is linear with sweep time or control voltage. The non-linear relationship of frequency to propagation velocity or electron beam velocity, and the resultant requirement for non-linear helix-to-cathode voltage is evident from Figure 4-2A and B. Since the control voltage is linear with sweep time or sweep frequency, the cancelling feedback must be developed in non-linear fashion, so that a non-linear cathode voltage-vs-frequency curve will result when the feedback is used to balance out a linear control voltage.

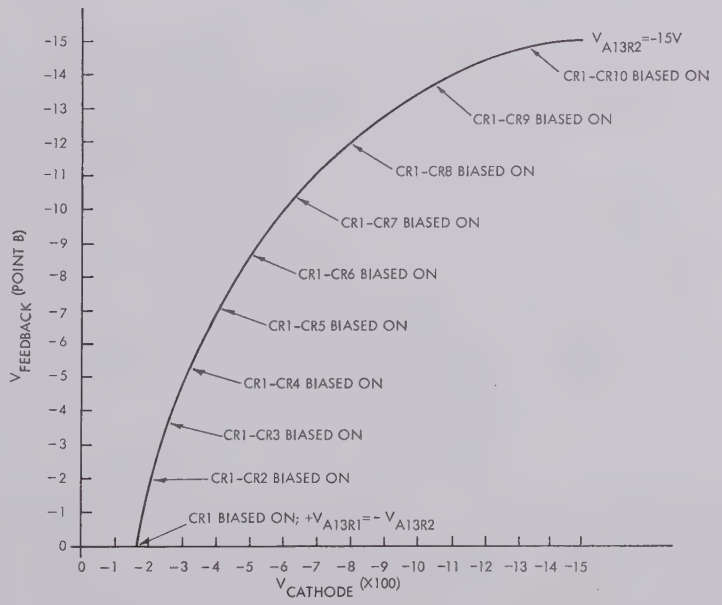
The diode shaper board provides this non-linear feedback by shunting away an increasing portion of the feedback current through a biased-diode ladder shunt network as the output level increases. This network is biased by a resistor string connected between + and -15 V, such that only one diode is conducting at the lowest supply voltage, and all diodes are conducting at the highest supply voltage, with a non-linear turn-on curve in between. Thus, an increase in the cathode supply voltage produces a feedback voltage increase at a slower rate (negative slope derivative) as shown in Figure 4-3B. Since the cathode supply circuit increases its voltage output until the control and feedback signals applied to its summing junction cancel, this means that a linear increase in control voltage drives the cathode supply output in non-linear fashion with a positive slope derivative, as shown in Figure 4-3B, to produce feedback cancellation.

The resultant cathode supply voltage vs frequency curve produces a linear frequency vs control voltage performance curve. Mathematically, the curve of required cathode supply voltage vs frequency (Figure 4-3C) approximates a third-order exponential function. By establishing a feedback curve that corresponds to the second derivative of that curve, a linear feedback voltage-vs-frequency curve is obtained at point B, since the second derivative of a third-order function is linear.

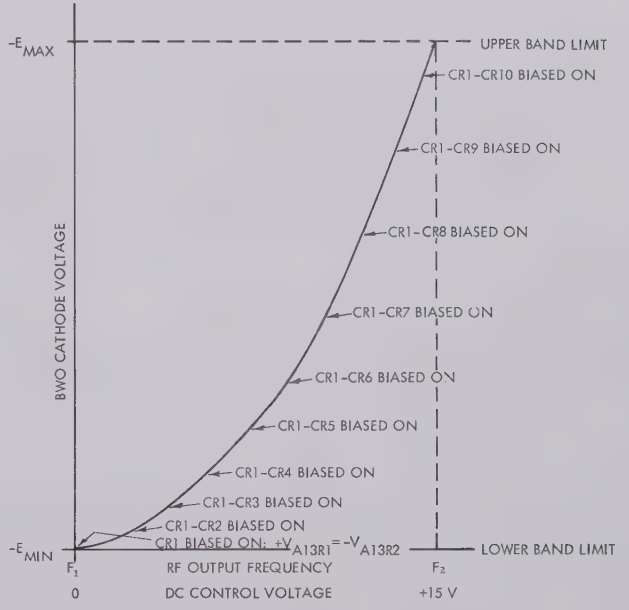
The feedback voltage supplied to the low-voltage diode shaper board at point A, after passing through dropping resistors R1



A. Simplified Schematic



B. Typical Diode Shaper Feedback Characteristic



C. Typical Overall Voltage vs. Frequency Characteristic for the Feedback-Controlled Cathode Supply

FIGURE 4-3. SIMPLIFIED SCHEMATIC AND OPERATING CHARACTERISTICS OF DIODE SHAPER BOARD

through R6, is a fixed fraction of the negative cathode supply output voltage. The feedback voltage developed between point A and ground is produced by the feedback current through A13R2. The ladder network, composed of diodes CR1 through CR10 and R1 through R11, achieves the feedback slope shown in Figure 4-3B by progressively shunting a greater percent of the feedback current away from R2 as the feedback level exceeds the "turn-on" voltage of each biased diode.

Amplifier stages Q1 and Q2 are emitter-follower stages that serve as an impedance converter amplifier to provide a low-impedance output at point B with the same voltage as the feedback level at point A. The point B output then serves as a suitable low-impedance source for summing junction feedback current through summing resistors A1R6 and A1R38 in the cathode supply.

Resistors A13R15 through A13R24 and diode A13CR11 establish the bias on the diode string, and are the same value in all shaper boards. Diode A13CR1 stabilizes the voltage at the junction of R15 and R16 as the current load changes during feedback shunting conditions. Resistors A13R1 through A13R11 are different for each plug-in unit model, and are selected to obtain the desired curve by shunting away a greater percent of the increasing feedback current as the feedback voltage level reaches the forward-biasing point for each diode. The overall effect is that the feedback voltage developed at point A rises as cathode voltage increases, but at a slower rate, because resistors A13R3 through A13R11 shunt away part of the current that would otherwise pass through A13R2 to develop feedback voltage between point A and ground.

The resultant feedback voltage curve (Figure 4-3B) is a smooth-curve approximation with nine (9) gradual slope changes as the feedback level reaches the turn-on points of A13CR2 through A13CR10. The decrease in slope at each turn-on point is related to the additional shunting effect of the individual resistance values of A13R3 through A13R11 and the net difference between the level at point A and the return voltage of each diode.

At the low band-edge output frequency, the cathode supply output voltage must have a negative value corresponding to the minimum bias requirement of the tube, while the control voltage is zero. Thus, a zero feedback voltage must be developed at a finite supply output level, as shown by the X-axis intercept of the curve in Figure 4-3B. This is accomplished by selecting the value of A13R1 and setting its return voltage (point D) at a positive level between 12.5 and 15 V by means of Start Frequency Adjust resistor A13R26. This positive offset circuit then biases point A positively until the cathode supply voltage increases to the point where the cathode supply feedback voltage supplied to point A equals the positive offset voltage. This establishes a 0-volt null at point A, as required for zero feedback voltage. As the control voltage is subsequently increased above 0 to +15 V, the feedback developed at point A increases non-linearly from 0 to -15 V.

The dc impedance converter amplifier (A13Q1 and A13Q2) consists of two cascaded emitter follower stages with the collectors held close to ground level by A13CR12. Diodes A13CR13 and A13CR14 compensate for the sum of the emitter-base drops in A13Q1 and A13Q2 when these transistors are biased to heavy conduction by a 0-level feedback signal at point A, thus developing a 0-level signal at point A'. As the feedback signal increases to the -15 V level, the conduction of A13Q1 and A13Q2 decreases so that the voltage at A' tracks that at point A, but has a higher source impedance to drive the summing junction.

The End Frequency Adjust resistor A13R28 provides an adjustment for the feedback current supplied from the diode shaper board to summing resistor A1R6 in the cathode supply. It can be used to adjust the overall slope of the diode shaper board curve by establishing the feedback level required to generate 1 ma feedback current to the summing junction at the upper band limit. This then sets the maximum cathode supply voltage limit corresponding to that required by the BWO tube for the upper band-limiting frequency. When the BWO tube is replaced, adjustment of A13R1 and A13R28 permits the feedback of the diode shaper board to be tailored to the characteristic of the new tube without requiring replacement of fixed resistors on the diode shaper board.

4.6 LEVELER-AMPLIFIER (see Figure 4-4).

4.6.1 GENERAL. The leveler-amplifier operates as a closed-loop differential error signal amplifier driving the grid of the BWO tube (via the transfer oscillator) to correct for differences between the control and sampler signal levels applied to the differential input stage through A11-B and A11-C. The leveler amplifier consists of a differential amplifier stage (A11Q1) followed by two emitter-follower stages (A11Q2 and A11Q3). There is also a single-stage amplifier (A11Q4) which drives the UNLEVELED WHEN LIT lamp.

With RF OUTPUT switch S2 in the LEVELED mode, the leveler amplifier receives an input signal through terminal A11-B from the rf sampler crystal detector, to drive one side of A11Q1. On units with an internal sampler, RF SAMPLER switch S1 selects either the internal or external sampler to drive the leveler amplifier. The rf sampler signal has an amplitude of at least -60 mv at a level corresponding to the maximum power available with full-band leveling.

The signal from the leveler reference output of the modulator is tapped from the POWER LEVEL control resistor R10 and applied through A11-C to the other side of dual transistor A11Q1. The signal level at R10 has a maximum amplitude of -300 mv corresponding to unmodulated output, and an amplitude of 0 V corresponding to "full off" modulation. With unmodulated output, the POWER LEVEL control R10 adjusts the level applied to A11-C between 300 mv and a minimum level set by the Minimum Power Level control R11, which is connected between R10 and ground. Adjustment of R11 sets the minimum level of the output provided by R10 between -60 mv and 0 mv.

The nominal minimum setting of about -20 mv corresponds to a square-law sampler output level 5 db below the nominal -60 mv which corresponds to the full-band-leveled power point. The maximum setting of -300 mv corresponds to sampler output of up to 7 db above the full-band-leveling point, to permit partial-band leveling at higher power levels in accordance with the tube characteristic.

4.6.2 LEVELER-AMPLIFIER OPERATION. If the level applied to A11-C is more negative than that supplied to A11-B, a condition of "insufficient rf output power" is indicated. In that case the relatively greater forward bias on the left half of A11Q1 causes it to conduct more heavily and take control of the differential stage. The result is that the base of A11Q2 is driven close to +15 V, reducing its conduction. The reduced conduction of A11Q2 isolates the base of A11Q3 from +15 V, thereby dropping the applied base voltage at that transistor and reducing its conduction. The result is a drop in the positive output signal supplied to the transfer oscillator through A11-E. This reduced control signal reduces the

amplitude of the grid driver output from the transfer oscillator. The reduced-amplitude driver output reduces the negative bias applied to the grid by the active modulator stage A12Q1 in the elevated supply, thereby increasing the rf power output from the BWO tube.

If the level applied to A11-B is more negative than that applied to A11-C, indicating "excessive output power," the amplifier stages respond in an opposite manner to increase the conduction of A11Q3 and thereby increase the positive output signal supplied to the modulator through A11-E. This increases the drive signal output of the transfer oscillator to increase the negative grid bias developed by A12Q1 in the elevated supply, thereby reducing the rf power output from the BWO tube.

In the LEVELED position of S2, the input to A11-B is obtained from either an external or internal sampler (as applicable), to provide the closed-loop level control operation described above. In the UNLEVELED position of S2, A11-B is connected to the +15 V supply through 100 K resistor R7. This assures that the base of the left half of Q2 is biased more positively than the base of the right half, a condition equivalent to the "insufficient output power" condition in the leveled mode. As a result, regardless of the setting of POWER LEVEL control R10, the right half of A11Q1 conducts only slightly, and A11Q3 is thereby biased to minimum conduction so that the output signal supplied to the modulator through A11-E is at 0 V.

Amplifier response is stabilized by a feedback loop consisting of A11C3 and A11R6 around the A11Q2 stage. Diode A11CR1 establishes a negative feedback path between the emitter-follower output resistor string in the A11Q3 stage and the base of the left half of A11Q1. This feedback limits the drop across A11R11 and prevents the output at terminal E from going more positive than +11V, thereby avoiding saturation of both the leveler and transfer oscillator. The A11CR1 feedback loop stabilizes leveler response when square-wave modulation is used by smoothing the delay interval between the modulator reference signal amplitude change at A11-C and the subsequent sampler signal change at A11-B. It permits the leveler to maintain control of the "power on" signal envelope without interfering with individual cycles of the square-wave modulation.

This feedback does not significantly degrade the leveling performance for the modulated signal envelope or for unmodulated CW signals, since level variations in such signals occur at a rate at least an order-of-magnitude slower than the rise and fall time of the square-wave modulation.

Diode A11CR2 prevents the output from going more negative than -1V, since the transfer oscillator Diode A11CR2 works only with positive signals. The leveler amplifier frequency response is set by the R-C bypass network A11C3-A11R6. This network prevents leveler oscillation by controlling the high-frequency gain and phase response.

4.6.3 UNLEVELED LIGHT OPERATION. Transistor A11Q4 controls the UNLEVELED WHEN LIT lamp DS1. This lamp is lit when +100 V is applied to it through A11R13. When S2 is in the UNLEVELED position, the output signal developed at A11-E is 0 V, as described above. In this case A11Q4 is held cut off, and DS1 is lighted. When the output signal at A11-E is continuously above 0 V, indicating that controlled leveling performance is taking place throughout the range being swept, the positive signal biases A11Q4 to conduction. A11Q4 then couples A11-H to ground and extinguishes DS1. If leveled performance is obtained over just a fraction of the range being swept, A11Q4 is turned on and off, and the capacitance of DS1 stabilizes the voltage at A11-H at a level that keeps DS1 lit.

4.7 ELEVATED SUPPLY

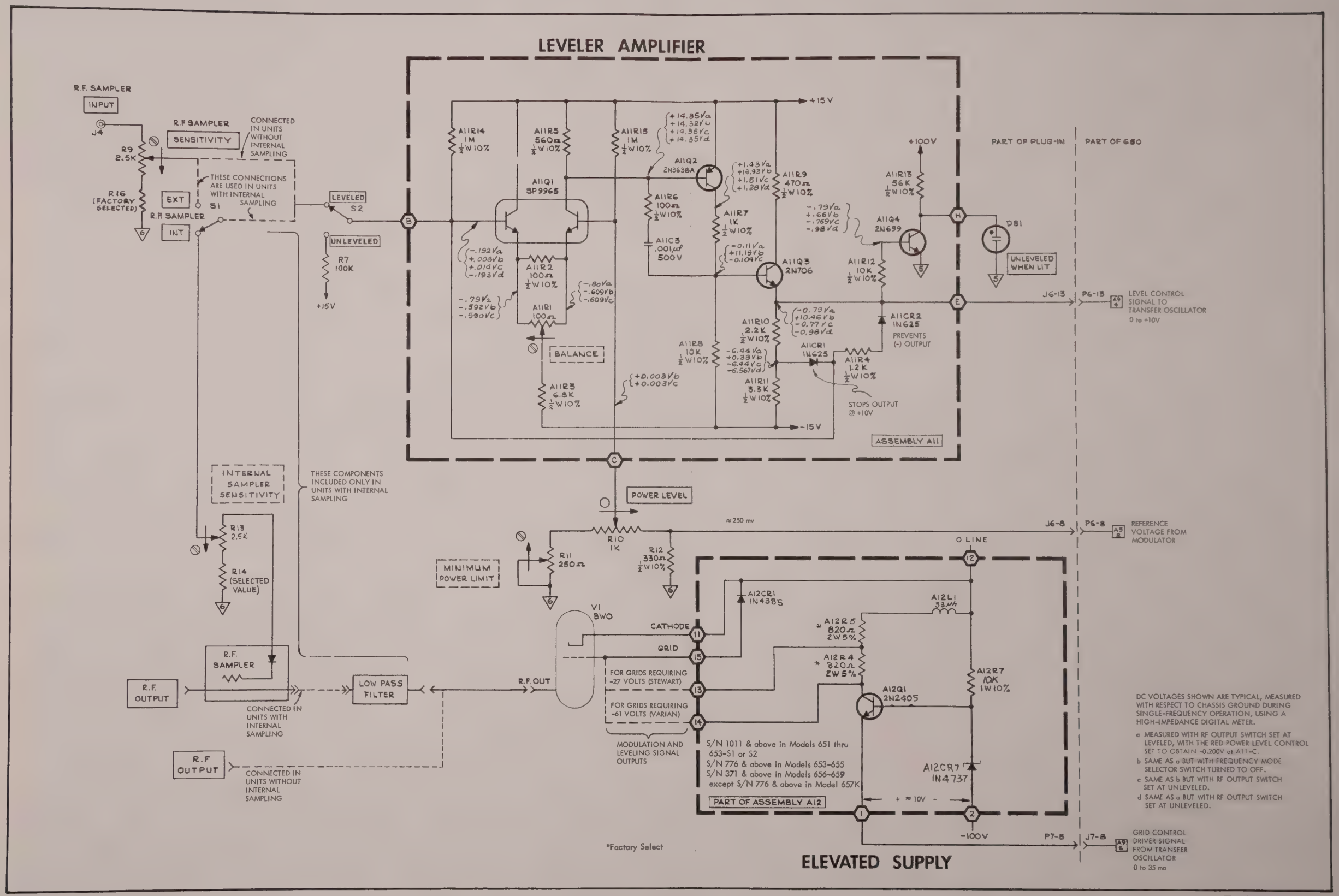
The passive circuits of the elevated supply PC Board A12 are illustrated and discussed individually in the paragraphs covering related circuits in the main chassis, in Section 4 of the Model 650 Instruction Manual.

The grid modulator A12Q1 is the only active stage in the elevated supply. Operating in the common-base configuration, it acts as an impedance converter and isolator for the output drive current developed by the transfer oscillator driver stage A9Q4.

After passing through A12Q1 the drive current develops the necessary grid bias across A12R5 to operate the grid at a voltage negative with respect to the cathode (0 line). For tube cut-off, a maximum driver/modulator current of 35 ma produces the necessary cut-off bias of -27 V. Diode A12CR1 prevents the grid from ever being driven positive with respect to the cathode.

4.8 LOW-PASS FILTER

Most plug-in unit models contain a low-pass filter as the first element in the rf output line from the BWO tube. This filter is a transmission-type resonant structure which attenuates rf harmonics generated by the BWO tube.



650-1, -3, -5

Revised 11/15/69

FIGURE 4-4
SIMPLIFIED SCHEMATIC OF PLUG-IN UNIT

SECTION 5

MAINTENANCE

NOTE: Main paragraph topics in this section are numbered to agree with similar paragraphs in the Model 650 Instruction Manual, which contains material pertinent to all plug-in units. This manual contains supplementary material pertinent to the plug-in "family" covered by this manual.

5.1 PERIODIC MAINTENANCE

Refer to Model 650 Instruction Manual.

5.2 VOLTAGE AND CURRENT MEASUREMENTS AT CHASSIS TEST POINTS.

WARNING

The voltages and current pickoffs pertaining to the plug-in unit, available at test points on the left side of the Model 650 chassis and the plug-in unit, are at high-voltage levels. Suitable high-voltage measurement techniques and precautions must be used. The cathode supply output (TP6) is measured with respect to chassis ground, and a high-voltage voltmeter or a high-voltage probe must be used. For all other high voltage measurements, the "0 line" (TP10) which is at or near cathode potential is the reference rather than chassis ground, and a floating voltmeter with at least 3000 volts insulation must be used. The heater supply output between TP7 and TP8 may be measured with high voltage off, using a standard meter. The lowest cathode supply output voltage, which in some plug-in units is low enough for measurement without an insulated meter, is obtained with a single-frequency setting at the low end of the band. Other high voltage measurements should be made at this setting of the cathode supply to keep the "0 line" voltage as low as possible for safety reasons.

a. Cathode Supply Voltage. [TP6 (-) to chassis ground (+)]. The proper cathode supply output voltages for the lower and upper band limit frequencies, corresponding to single-frequency settings of 0 and 100 on the logging scale, are given in Addendum A in the envelope at the rear of this manual. When a replacement BWO tube has been installed, refer instead to the manufacturer's data sheet for the tube, which should be in the same envelope. Make the dc voltage measurement with a high voltage digital meter or suitable voltage-divider probe. Refer to Paragraph 5.3.4 of this manual for measurement of ripple effects.

b. Heater Voltage. [TP7 (+) to TP8 (-)]. All Stewart BWO tubes utilize less than 1.2 amperes heater current, so that the proper heater voltage with one of these plug-in units loading the supply is 6.3 V ± 0.1 V. It is recommended that this voltage be measured with the high voltage turned off by removing the top or rear panel to defeat the interlock switch. If the measurement is made with high voltage on, the heater will be at cathode potential, and a floating, insulated voltmeter must be used.

c. -100 V Supply. [TP10 (+) to TP11 (-)]. Voltage should be 100 ± 0.1 V. For this measurement, the instrument must be operating with the FREQUENCY Mode Selector switch set to SINGLE, and with no modulation applied. The measurement must be made using a floating, insulated voltmeter.

d. Anode Supply. [TP9 (+) to TP10 (-)]. The proper anode supply voltage output is given in Addendum A in the envelope at the rear of this manual. When a replacement BWO tube has been installed, refer instead to the manufacturer's data sheet for the tube, which should be in the same envelope. The measurement must be made using a floating, insulated voltmeter.

e. Grid Voltage. [TP10 (+) to TP23 (-)]. Voltage should be 27 ± 2 V with controls set for RF ON (unmodulated); and less than 1 V with the FREQUENCY Mode Selector switch in the OFF position. The measurement must be made using a floating, insulated voltmeter.

f. Collector Current. [TP1 (+) to TP21 (-)]. The proper collector currents in ma for the lower band limit, center, and upper band limit frequencies, corresponding to single-frequency settings of 0, 50, and 100 on the logging scale, are given in Addendum A in the envelope at the rear of this manual. When a replacement BWO tube has been installed, refer instead to the manufacturer's data sheet for the tube, which should be in the same envelope.

To measure the collector current, measure the voltage drop between TP1 (+) and TP21 (-). This is the voltage drop produced across a 10-ohm resistor by the collector current. Hence, the voltage measured in millivolts must be divided by 10 to obtain the current in milliamperes.

CAUTION

This voltage measurement is at the level of +100 V, since TP1 is the +100 V test point. Thus, the voltmeter used must be floating, but need not be a high-voltage unit.

g. Helix Current. [TP22 (-), TP3 or chassis ground (+)]. The proper helix currents in ma for the lower band limit, center, and upper band limit frequencies, corresponding to single-frequency settings of 0, 50, and 100 on the logging scale, are given in Addendum A in the envelope at the rear of this manual. When a replacement tube has been installed, refer instead to the manufacturer's data sheet for the tube, which should be in the same envelope.

To measure the helix current, measure the voltage drop between TP22 and TP3 (or chassis ground). This is the voltage drop produced across a 100-ohm resistance by the helix current. Hence, the voltage measured in millivolts must be divided by 100 to obtain the current in milliamperes. This voltage measurement is at ground level so that a floating or higher-voltage voltmeter need not be used.

NOTE: The helix overcurrent trip-out level for Stewart BWO tubes is set at 5 ma.

5.3 INTERNAL ADJUSTMENTS.

5.3.1 AVAILABLE ADJUSTMENTS. There are six internal adjustments in each plug-in unit. The instrument is designed for long-term operation with a minimum of adjustment. The main purpose of the adjustments provided is to simplify the recalibration of the plug-in unit after installation of a new BWO tube or other components. These adjustments can also be

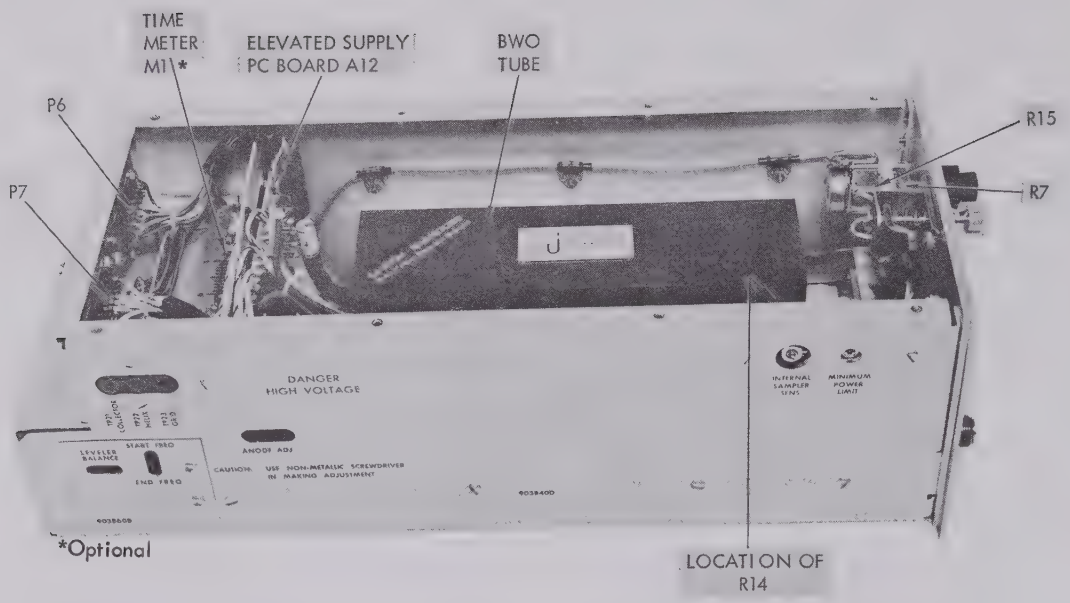


FIGURE 5-1. TOP VIEW OF PLUG-IN UNIT CHASSIS

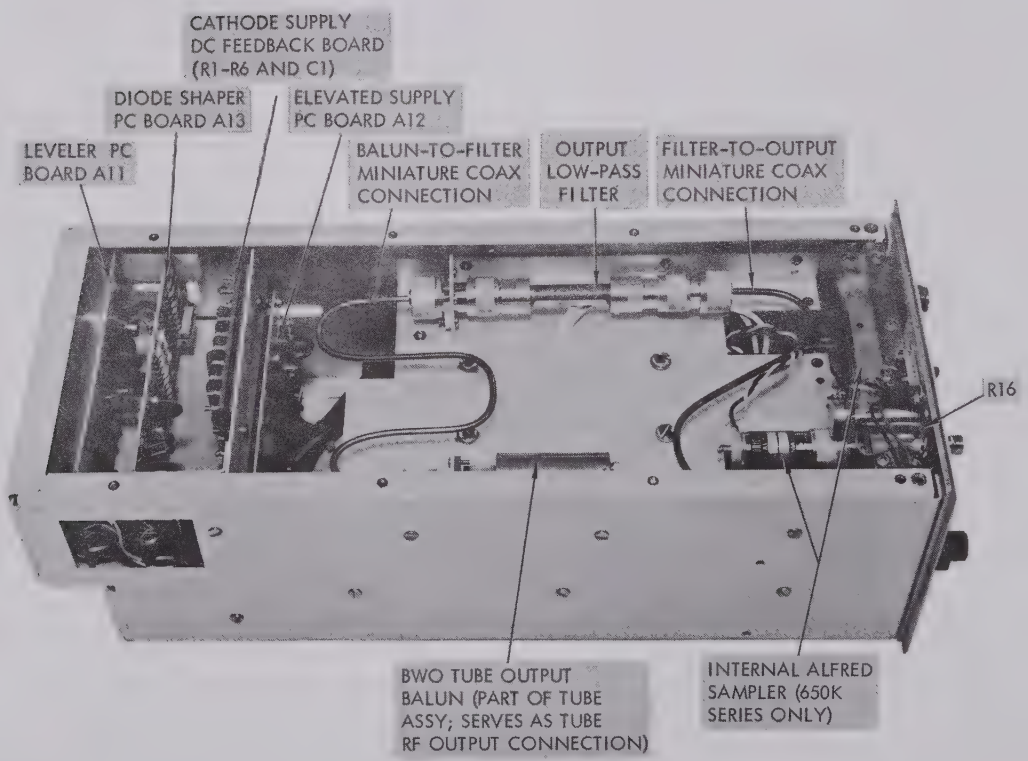

CATHODE SUPPLY DC FEEDBACK BOARD (R1-R6 AND C1)
DIODE SHAPER PC BOARD A13
ELEVATED SUPPLY PC BOARD A12
LEVELER PC BOARD A11
BALUN-TO-FILTER MINIATURE COAX CONNECTION
OUTPUT LOW-PASS FILTER
FILTER-TO-OUTPUT MINIATURE COAX CONNECTION
R16
BWO TUBE OUTPUT BALUN (PART OF TUBE ASSY; SERVES AS TUBE RF OUTPUT CONNECTION)
INTERNAL ALFRED SAMPLER (650K SERIES ONLY)

FIGURE 5-2. BOTTOM VIEW OF PLUG-IN UNIT CHASSIS

used for periodic recalibration at six-month intervals or as required. The adjustments and a recommended adjustment procedure for each, are described in the paragraph below. These procedures permit the plug-in unit to be calibrated to meet published specifications, when operating in a Model 650 main chassis which has been factory calibrated or field-calibrated with a Sweep Oscillator Calibration Plug-in unit, Model 650T.

A factory calibration service is available at nominal cost by returning the instrument to ALFRED. Contact your nearest representative or our sales department.

NOTE: Refer to the Model 650 Instruction Manual for adjustment procedures for the heater supply voltage (A6R21 HEATER ADJ., Paragraph 5.3.3), the -100 V supply voltage (A6R5 GRID ADJ., Paragraph 5.3.3). These adjustments are accessible from the top of the Model 650 chassis, as shown in Figure 5-1 of the Model 650 Instruction Manual.

5.3.2 ADJUSTMENT PROCEDURES. (All adjustments are shown in Figure 5-2 of the Model 650 Instruction Manual.)

CAUTION

Use a non-metallic screwdriver in making these adjustments. Use of a metallic screwdriver can

(1) Damage magnetic focus of microwave tube
(2) Cause circuit-damaging shorts in the area between the access opening and the adjustment screw.

1. A11R1 LEVELER BALANCE Adjustment. This adjustment is used to balance the base-emitter voltages of the input dual transistor A11Q1. These voltages do not change with age. Unless the factory adjustment is altered improperly, readjustment should be required only when A11Q1 is replaced. At that time, A11R1 should be carefully set to provide a proper balance between the extremes of (1) keeping the UNLEVELED light on improperly when the output is leveled, and (2) obtaining overshoot in the leveled response, particularly at the rf turn-on step function after retrace blanking or during square wave modulation.

   To adjust the LEVELER BALANCE, proceed as follows:

   a. With the plug-in unit installed in a Model 650, make the following control settings:

      FREQUENCY Mode Selector to OFF.
      MODULATION Mode Selector to AM OFF.
      RF OUTPUT to LEVELED.
      (Red POWER LEVEL control and RF SAMPLER INT-EXT switch, where present, can be at any position.)

   b. Adjust the LEVELER BALANCE control A11R1 until the UNLEVELED light just goes out.

   c. Connect the RF OUTPUT jack through a suitable attenuator to a detector, and connect the detector output to the vertical channel of an oscilloscope (see Figure 5-3). Use a 47-ohm resistor to terminate the detector cable at the oscilloscope to provide a proper load for the crystal. Use the OUTPUT SWEEP signal to drive the oscilloscope horizontal channel.

   NOTE: On units without internal sampling, connect an external sampler or a directional coupler and detector to drive the SAMPLER INPUT jack. This sampler or coupler should be connected between the RF OUTPUT jack and the attenuator/detector described in Step c above.

   d. Make the following changes in control settings:

      FREQUENCY Mode Selector to SINGLE.
      SINGLE Frequency Selector to F_0.
      MODULATION Mode Selector to SQ WAVE
      RF SAMPLER switch to INT (if applicable).
      POWER LEVEL control to mid-range.

   e. Examine the CRT presentation for excess overshoot on the "rf on" step. Adjust the LEVELER BALANCE control A11R1 slightly, just enough to eliminate any overshoot.

   NOTE: If too much adjustment is made, the square-wave symmetry may be degraded.

   f. Turn the F_0 control to manually sweep the output signal frequency across the band while examining the leveled square wave trace on the CRT for absence of overshoot or poor symmetry. Make a slight re-adjustment of the LEVELER BALANCE control A11R1 if necessary.

   g. Turn the POWER LEVEL control CCW to reduce the output level over a 5-db range below the full-band-leveled point. Again examine the leveled square wave trace on the CRT for absence of overshoot or poor symmetry. Make a slight re-adjustment of the LEVELER BALANCE control A11R1 if necessary.

2. A12R9 ANODE ADJ. Adjustment. This control is used for fine adjustment of the anode voltage supplied to the BWO tube after installation of the proper-value resistor in the A12R14 circuit position. Re-adjustment will usually be required when the BWO tube is replaced, and may also be useful to restore the power output level of an aging BWO tube. Since the final criteria of a proper anode voltage adjustment (assuming other voltages are correct) is that rated output power is obtained, the final adjustment of anode voltage should be made in terms of output power, in accordance with the procedure given in Paragraph 5.3.5 of this manual. A preliminary adjustment of anode voltage to the operating value specified in the manufacturer's data sheet for a newly installed BWO tube can be made using the following procedure. To check anode voltage in older tubes, use the procedure of Paragraph 5.3.5.

   a. Determine the operating value for anode voltage specified on the manufacturer's data sheet (located in the envelope at the rear of this manual). Use this voltage value and the graph given in Figure 5-8 of the Model 650 Instruction Manual to determine the correct value for feedback resistor A12R14 at the top of the elevated supply PC board in the plug-in unit.

   b. If the value of A12R14 determined in Step a differs from the resistor actually installed in the unit, change A12R12 to the proper value.

   c. Measure the anode voltage between TP9 (+) and TP10 (-), and adjust it to the value determined in Step a, by using A12R9 ANODE ADJ.

   WARNING

   This is a high-voltage measurement. Use a floating, insulated voltmeter.

   d. Refer to Paragraph 5.3.5 for a final adjustment of anode voltage in terms of output power.

3., 4. A13R26 START FREQ and A13R28 END FREQ. Adjustments. These controls are used to set the cathode supply feedback limits to obtain the proper cathode supply

output voltage limits for the BWO tube, corresponding to the lower and upper frequency limits of the plug-in unit. The proper voltages for these band limits can be checked as described in Paragraph 5.2 a above.

Adjustment of these voltages to the prescribed values is the first step in frequency calibration of the plug-in unit. Final frequency calibration involves a further adjustment of A13R26 and A13R28 to obtain calibrated frequency performance. Once final frequency calibration of the plug-in unit has been carried out using the procedure given in Paragraph 5.3.3, these voltages should not be re-adjusted.

Refer to Paragraph 5.3.3 for the proper adjustment procedure.

5. R13 INTERNAL SAMPLER SENS. Adjustment (on instrument models with K-suffix numbers only). This control is used to set the signal level applied to the leveler-amplifier from the internal rf sampler. The proper adjustment for standard applications is one that places the full-band-leveling point at the center of the adjustment range of the red POWER LEVEL control, and provides unleveled output with the POWER LEVEL control turned fully CW. This allows the POWER LEVEL control to be set above the full-band-leveled position for higher-level, partial-band leveling, and also provides an adjustment range of at least 5 db below full-band-leveled power when the POWER LEVEL control is turned fully CCW. Note that this control affects only operation with the internal rf sampler. When an external sampler is used, the front panel RF SAMPLER SENS. control provides a similar adjustment function. In achieving a sufficient amount of reduction below the full-band-leveled point, a readjustment of the MINIMUM POWER LIMIT control R11 may also be required.

   The adjustment procedure is as follows:

   a. Connect the RF OUTPUT jack through a suitable attenuator to a crystal detector, and connect the detector output to the vertical channel of an oscilloscope. Use the OUTPUT SWEEP signal to drive the horizontal channel of the oscilloscope.

   b. Make the following control settings:

      RF OUTPUT to LEVELED
      RF SAMPLER to INT
      FREQUENCY Mode Selector to SWEEP $F_1 \rightarrow F_2$
      MARKER AMPLITUDE to OFF
      MODULATION to AM OFF
      SWEEP TIME to .01
      SWEEP TRIGGER to FREE RUN
      F_1 to 0 on the logging scale
      F_2 to 100 on the logging scale
      POWER LEVEL (red) fully CW.

   c. Adjust the INTERNAL SAMPLER SENS adjustment until the maximum-power excursion of the unleveled CRT presentation appears flattened, indicating the start of leveled response. Then back off the adjustment so that the unleveled trace remains unaffected with the red POWER LEVEL control remaining fully CW.

   d. Turn the red POWER LEVEL control CCW slowly and observe the onset of leveled performance across the band. Full-band leveling should be achieved at a mid-range setting of the POWER LEVEL control.

   e. With the red POWER LEVEL control set at the maximum power level that allows full-band-leveling, adjust the oscilloscope vertical amplification to obtain a full-height presentation on the CRT.

   f. Turn the red POWER LEVEL control fully CCW. With the oscilloscope amplification set as above, and the input to the crystal detector attenuated sufficiently that square-law operation is assured, the presentation on the CRT should be reduced to less than 1/3 of the amplitude observed in Step e. If not, adjust the MINIMUM POWER LIMIT adjustment R11 to achieve such a reduction in level.

6. R11 MINIMUM POWER LIMIT Adjustment. This control is used to set the range of the red POWER LEVEL control by adjusting its lower limit. It does not affect the upper limit of the control range.

   The adjustment procedure for units with internal sampling is included as the final step in the INTERNAL SAMPLER SENS adjustment procedure, item 5 above. For units without internal sampling, use the following procedure:

   a. Connect a suitable external sampler loop, consisting of a sampler or a directional coupler and detector, to the RF OUTPUT jack, and use the sampler output to drive the RF SAMPLER INPUT jack (see Figure 5-3). Terminate the rf loop with a suitable attenuator and crystal detector, and connect the detector output to the vertical channel of an oscilloscope. Use the OUTPUT SWEEP signal to drive the horizontal channel of the oscilloscope.

   b. Make the following control settings:

      RF OUTPUT to LEVELED
      RF SAMPLER to EXT
      FREQUENCY Mode Selector to SWEEP $F_1 \rightarrow F_2$
      MARKER AMPLITUDE to OFF
      MODULATION to AM OFF
      SWEEP TIME to .01
      F_1 to 0 on the logging scale
      F_2 to 100 on the logging scale
      Red POWER LEVEL fully CW.

   c. Adjust the front panel RF SAMPLER SENS control until the maximum-power excursion of the unleveled CRT presentation appears flattened, indicating the start of leveled response. Then back off the adjustment so that the unleveled trace remains unaffected with the red POWER LEVEL control remaining fully CW.

   d. Turn the red POWER LEVEL control CCW slowly and observe the onset of leveled performance across the band. Full-band leveling should be achieved at a mid-range setting of the POWER LEVEL control.

   e. With the red POWER LEVEL control set at the maximum power level that allows full-band-leveling, adjust the oscilloscope vertical amplification to obtain a full-height presentation on the CRT.

   f. Turn the red POWER LEVEL control fully CCW. With the oscilloscope amplification set as above, and the input to the crystal detector attenuated sufficiently that square-law operation is assured, the presentation on the CRT should be reduced to less than 1/3 of the amplitude observed in Step e. If not, adjust the MINIMUM POWER LIMIT adjustment R11 to achieve such a reduction in level.

5.3.3 FREQUENCY CALIBRATION ADJUSTMENT. (See Figure 5-3.)

The following procedure should be used for periodic frequency calibration of the plug-in unit.

CAUTION

Check all supply voltages except the cathode supply output before performing this calibration adjustment. (See Paragraph 5.2.)

a. Let the instrument warm up and stabilize for about 1/2 hour.

b. Make the following control settings:

RF OUTPUT to UNLEVELED
FREQUENCY Mode Selector to SINGLE
SINGLE Frequency Selector to F_0
MARKER AMPLITUDE to OFF
MODULATION to AM OFF
SWEEP TIME to .01
SWEEP TRIGGER to FREE RUN

c. With the instrument operating unmodulated in single-frequency mode, measure the cathode supply voltage output at the lower and upper band limit frequencies as directed in Paragraph 5.2 a.

d. If either voltage measured in Step c is incorrect, adjust it to the proper value using the START FREQ or END FREQ adjustment controls. (The START FREQ adjustment sets the voltage at the low band-edge frequency, and the END FREQ adjustment sets the voltage at the high band-edge frequency.)

e. Connect an rf test loop consisting of a variable attenuator, wavemeter, and crystal detector to the RF OUTPUT jack, and connect the crystal detector output to the vertical channel input of an oscilloscope. Use the OUTPUT SWEEP signal to drive the horizontal channel of the oscilloscope.

f. Make the following changes in control settings:

FREQUENCY Mode Selector to SWEEP $F_0 \pm \Delta F$
RETRACE to OFF
ΔF AMPLITUDE fully CW
SWEEP TIME to .01
SWEEP TRIGGER to FREE RUN
F_0 to 0 on the logging scale (the low band-edge frequency).

g. Adjust the wavemeter to the low band-edge dial frequency.

h. Observe the CRT presentation. The wavemeter pip should appear exactly in the center of the trace. If it is obviously off-center, adjust the START FREQ control to move the pip to the center of the trace.

i. When the pip appears centered in Step h above, turn the ΔF AMPLITUDE control CCW slowly, continuing to the CCW rotation limit (labeled OFF) unless the pip appears off center as the control is turned. If necessary, stop turning the ΔF AMPLITUDE control, and adjust the START FREQ control again to restore the pip to the center of the trace. Continue this procedure until the ΔF AMPLITUDE control is fully CCW and the wavemeter pip remains in the center of the trace.

j. Adjust the wavemeter to the high band-edge dial frequency.

k. Adjust the F_0 FREQUENCY control to 100 on the logging scale, and turn the ΔF AMPLITUDE control fully CW.

l. Observe the CRT presentation. The wavemeter pip should appear exactly in the center of the trace. If it is obviously off-center, adjust the END FREQ control to move the pip to the center of the trace.

m. When the pip appears centered in Step k above, turn the ΔF AMPLITUDE control CCW slowly, continuing to the CCW rotation limit (labeled O) unless the pip appears off center as the control is turned. If necessary, stop turning the ΔF AMPLITUDE control, and adjust the END FREQ control again, to restore the pip to the center of the trace. Continue this procedure until the ΔF AMPLITUDE control is fully CCW and the wavemeter pip remains in the center of the trace.

n. Adjust the F_0 FREQUENCY control to 0 on the logging scale and turn the ΔF AMPLITUDE control fully CW.

o. Repeat Steps g through m.

p. Repeat Steps n and o one additional time. Repeating the steps is necessary because of the interaction of the START FREQ adjustment A13R26 and END FREQ adjustment A13R28.

q. Check the frequency tracking across the dial at several points by turning the ΔF AMPLITUDE control to MAX and setting both the F_0 control and the wavemeter to identical frequencies. Frequency accuracy should be ±1% [redacted] or better across the band. If necessary, Steps g through p above may be repeated to offset the end frequencies slightly in order to reduce mid-band inaccuracies.

r. If it is desired to check residual FM and AM, retain the test set-up and follow the procedures of Paragraph 5.3.4.

5.3.4 CHECKOUT PROCEDURE FOR RESIDUAL FM AND AM. (See Figure 5-3.)

The following procedure may be used for periodic verification that residual FM and AM are within specification limits. It should be performed as a continuation of the frequency calibration adjustment procedure given in Paragraph 5.3.3 above. The FM procedure should be performed at the low-frequency end of the band, because residual FM effects are greatest at that point; and the AM procedure should be performed at the high-frequency end of the band.

a. The instrument should be operating with an rf test loop equivalent to Step e of Paragraph 5.3.3. To permit the high sensitivity readings required later in the procedure, the oscilloscope should be set for AC coupling.

b. Make control settings as in Step f of Paragraph 5.3.3, except turn the RETRACE control to ON. Also set the RF OUTPUT control to UNLEVELED and turn the MARKER AMPLITUDE and MODULATION both off.

c. Adjust the wavemeter to center its pip on the CRT display.

d. Slowly turn the ΔF AMPLITUDE control CCW, while adjusting the wavemeter slightly, as necessary to keep the wavemeter pip centered on the CRT trace. Continue this procedure until the ΔF AMPLITUDE control is fully CCW.

e. Set the wavemeter to place one-half of its pip at the left edge of the trace.

f. Adjust the oscilloscope horizontal sensitivity to yield a full-graticule sweep width while being driven by the OUTPUT SWEEP signal of the Model 650.

g. Adjust the oscilloscope for maximum vertical sensitivity, and set the vertical position so that the CRT presentation shows a sloping line which represents one half of the magnified wavemeter pip at the left edge.

h. Adjust the wavemeter enough to move the sloping line (pip) from one edge of the CRT presentation to the other. The difference between the wavemeter settings at each edge of the trace will calibrate the horizontal scale (typical value = 20 mc).

NOTE: Since the rf output is being left on during retrace, there will be two parallel lines visible on the CRT. Use the brighter line for the residual FM check (the dim line is the retrace indication).

i. Adjust the wavemeter slightly to move the sloping line to a convenient point on the graticule.

j. Observe the horizontal jitter in the line while the ΔF AMPLITUDE control remains fully CCW. The horizontal scale calibration made in Step h above will permit evaluating the frequency deviation of the jitter.

This deviation should be less than ± the Kc value indicated for "Maximum Residual FM" in Table 1-1. If excess residual FM is present, check the ripple voltage on the cathode supply [TP6 (-), TP3 (+); chassis ground]. Use an oscilloscope with a 10:1 divider probe and operate the vertical channel with ac coupling. The ripple voltage should not exceed ± 0.01% of the cathode supply output voltage at any point. Refer to the trouble-shooting procedures for the cathode supply in the Model 650 Instruction Manual if excess ripple is present. If excess power supply ripple is not present, the excess residual FM may be due to arcing or other breakdown in the BWO tube, which requires replacement of the tube.

NOTE: If desired, the above residual FM checkout procedure may be repeated at other frequencies in the frequency range of the plug-in unit. Since arcing or other breakdown effects in a BWO tube often show up initially as excess residual FM, this procedure can be useful in evaluating performance of aging BWO tubes.

k. Make the following changes in control settings, in preparation for the residual AM test.

FREQUENCY Mode Selector to SINGLE
SINGLE Frequency Control to F_0
F_0 control set at high end of band
MODULATION to SQUARE WAVE

l. Adjust the wavemeter away from the frequency of interest, or remove it from the circuit completely, as desired. Make sure that sufficient attenuation is provided in the rf test loop to allow the crystal detector to operate in its square-law range.

m. Adjust the oscilloscope for a free-running horizontal sweep independent of the Model 650. Leave the oscilloscope vertical input ac-coupled. Adjust the oscilloscope vertical sensitivity to obtain a square-wave height of 5 scale divisions (5 cm) on the graticule.

n. Turn the MODULATION switch to AM OFF.

o. Without changing the vertical sensitivity vernier adjustment of the oscilloscope from the setting used to obtain a full-height display in Step m, set the oscilloscope vertical sensitivity switch to step-increase vertical amplification by a factor of 10 (so that the full-height square-wave presentation would now be 50 scale divisions). Adjust the zero position control as necessary to place the unmodulated power-on straight line trace at a convenient line on the graticule.

p. Observe the vertical ripple on the CRT trace. It must not exceed 1 scale division (i. e. less than 1/50 or 2% of the output amplitude). If excess residual AM is present, refer to the trouble-shooting procedures for the anode and -100 V supplies in the Model 650 Instruction Manual.

5.3.5 POWER CALIBRATION ADJUSTMENT. (See Figure 5-4.) The following adjustment procedure can be used to check and adjust the power output level of the plug-in unit.

a. For newly installed BWO tubes, check and adjust the anode voltage to the specified level using the ANODE ADJ control as directed in Paragraph 5.3.2. For adjustment of older tubes, proceed as follows:

b. Connect an rf test loop consisting of a suitable attenuator pad, a thermistor mount, and a power meter to the RF OUTPUT jack to measure absolute power. Be sure to use a large enough attenuator to avoid exceeding the thermistor power rating. Alternately, an ALFRED 8000/7051 Oscilloscope/Sweep Network Analyzer system can be used for making direct absolute power measurements with a crystal detector.

c. Make the following control settings:

RF OUTPUT to UNLEVELED
FREQUENCY Mode Selector to SWEEP $F_1 \rightarrow F_2$
MARKER AMPLITUDE to OFF
MODULATION to AM OFF
SWEEP TIME to 10
SWEEP TRIGGER to FREE RUN
F_1 to 0 on the logging scale
F_2 to 100 on the logging scale.

d. Observe the unleveled power output characteristic. If power at any point in the sweep is below the level specified in Table 1-1, increase the anode voltage slightly using the ANODE ADJ control.

NOTE: The ANODE ADJ control permits an adjustment range of about ± 10 V. Since the anode voltage specified on the Stewart data sheet is only approximate, it may be necessary to increase the anode voltage by more than the ANODE ADJ control range to achieve rated power at the time of installation, and/or after long service. To do this, substitute a slightly higher resistance value for A12R14 (see Figure 5-8 in the Model 650 Instruction Manual), and then set the ANODE ADJ control.

WARNING

Turn power off when changing A12R14.

CAUTION

Do not increase the anode supply voltage more than necessary to bring the minimum power point up to specifications. In addition, the anode supply voltage should never be adjusted beyond the maximum operating level shown on the manufacturer's data sheet, nor should it be adjusted to the point where helix or anode current exceeds the manufacturer's specified maximum operating limit. Any increase in anode voltage will reduce the operating life of the BWO tube. If rated power output cannot be obtained with a reasonable anode voltage, and other tube operating voltages are correct, the BWO tube must be replaced.

e. For units with internal sampling, set the RF OUTPUT control

to LEVELED and the RF SAMPLER switch to INT. Then check the leveled power characteristic across the band, and also check leveler response to the POWER LEVEL control. The maximum power output obtainable with full-band leveling should occur at a mid-range setting of the POWER LEVEL control, and should equal or exceed the level specified in Table 1-1. Also check the leveled power variation across the band. The variation across the entire band should not exceed the amount specified in Table 1-1. If the unit does not meet leveled output specifications, check the LEVELER BALANCE and INTERNAL SAMPLER SENS. adjustments as directed in Paragraph 5.3.2.

f. For units which require external sampling, set the RF OUTPUT control to LEVELED. Connect a suitable external rf sampler loop to drive the RF SAMPLER INPUT jack, as shown in Figure 5-3, by inserting a sampler or a coupler and detector between the RF OUTPUT jack and the attenuator pad. With a suitable sampler and a proper adjustment of the RF SAMPLER SENS. panel control, it should be possible to obtain full-band leveling with a mid-range setting of the POWER LEVEL control; and response to adjustment of the POWER LEVEL control above and below the full-band leveling point should be as described in the Model 650 Instruction Manual. The maximum power output obtainable with full-band leveling should approximately equal the level specified in Table 1-1. The leveled power variation across the band should not greatly exceed the amount specified in Table 1-1. (An optimum external sampler loop using flat components can achieve the minimum variation specifications given in Table 1-1.) If leveler performance is unsatisfactory and the external sampler loop is known to be adequate, check the LEVELER BALANCE adjustment as directed in Paragraph 5.3.2.

5.4 TROUBLE SHOOTING.

NOTE: Refer to Paragraph 5.4 of the Model 650 Instruction Manual. The following material is supplementary to that manual.

5.4.1 BWO TUBE AGING AND FAILURE. There are three general indications of BWO tube aging: (1) reduced rf output throughout the operating band; (2) complete loss of rf output at one or more frequencies in the operating band; (3) repeated tripout of the helix overcurrent protection relay when operating unleveled with full output power, particularly in the upper portion of the operating band. Indications (1) and (2) above are usually caused by reduced cathode emission, while gas ionization in the BWO tube causes indication (3). Indication (2) at either band limit can be caused by a defective cathode supply or a defective or mis-adjusted diode shaper board that produces cathode voltage outside the proper tuning range. Normal aging of the BWO tube does not produce frequency calibration error; but internal arcing or other breakdown can produce excess residual fm.

To localize trouble to the BWO tube when indications of the above type are present, check all tube voltages and currents in accordance with Paragraph 5.2 above, and make adjustments as necessary following the procedures of Paragraph 5.3. If proper operation is not restored with proper voltages applied, and the BWO tube is still in warranty, read the Tube Warranty and Replacement Procedure at the rear of this manual and follow the specified return procedure. If the tube warranty has expired, refer to the procedure of Paragraph 5.3.5 and try increasing the anode voltage above the normal level to restore power output, before discarding the tube.

NOTE: Where failure is due to gas ionization, no adjustment of voltages will restore normal, full-band operation. If desired, the tube can still be used within a restricted tuning range, at frequencies below the point where excessive helix current occurs.

5.4.2 LEVELER IMBALANCE OR FAILURE. When the LEVELER BALANCE adjustment is not set properly, the UNLEVELED light will not faithfully track the occurrence of fully leveled response over the band being swept. The light may stay on continually, or it may work OK with internal leveling but not on external leveling. An improper balance adjustment in the opposite direction can also produce excess overshoot on the rf trace turn-on at the end of the "retrace off" interval, and a lesser overshoot on individual cycles of square-wave modulation. When any of these indications occur, re-adjust the LEVELER BALANCE control as directed in Paragraph 5.3.2. If the LEVELER BALANCE adjustment cannot restore proper operation, make voltage measurements in the leveler-amplifier circuit under operating conditions, as indicated in Figure 4-4, to locate the defective component or to localize the trouble to the transfer oscillator or elevated supply.

5.4.3 LEVELER-AMPLIFIER COMPONENT SELECTION. After replacement of the BWO tube it may be necessary to change the values of starred components indicated on the schematic diagram and on Figure 4-4. If oscillatory amplitude variations occur in leveled operation, the capacitance value of A11C3 must be increased, and the value of A11R6 must be reduced so that the R-C product of A11R6 x A11C3 remains constant.

If the leveler response exhibits slow-rise characteristics, it may be necessary to reduce the capacitance value of A11C3. In that event, also increase A11R6 so that the product of A11C3 x A11R6 remains constant. The value of A11C3 must not be reduced enough to cause oscillatory leveler operation.

NOTE: The allowable adjustment range of A11C3 is 0.1 to 0.0005 μf (0.002 μf nominal).

5.4.4 ELEVATED SUPPLY FAILURE. When failure is suspected in the Elevated Supply PC Board A12, all the passive components can be checked with power turned off. If the passive components are satisfactory, and the correct grid voltage is not produced with suitable drive from the modulator, check the performance of A12Q1 by substitution.

5.4.5 DIODE SHAPER BOARD FAILURE. If the proper voltages cannot be obtained when adjusting the START FREQ and END FREQ adjustment controls, and voltage measurements on the cathode supply feedback amplifier indicate that it is operating properly, check the performance of the diode shaper board. Typical operating voltages on the resistor biasing string are indicated in Figure 4-3. Performance of the diodes can be checked with power off by using an ohmmeter to measure forward and reverse resistance. To avoid overloads, do not use any range where open-circuit voltage exceeds 1.5 V, or short-circuit current exceeds 3 ma. In-circuit voltage checks may also be used to check A13Q1, A13Q2, A13CR13 and A13CR14.

5.4.6 INTERNAL SAMPLER FAILURE. If the instrument operates properly with an external sampler known to be in good condition, but performance with internal sampling is unsatisfactory, check the crystal detector on the internal sampler by substitution. If the internal sampler or its crystal detector are replaced, reset the Internal Sampler Sens. adjustment R13 following the procedure of Paragraph 5.3.2. If full-band leveling cannot be obtained at a suitable setting of the POWER LEVEL control with the Internal Sampler Sens. adjustment

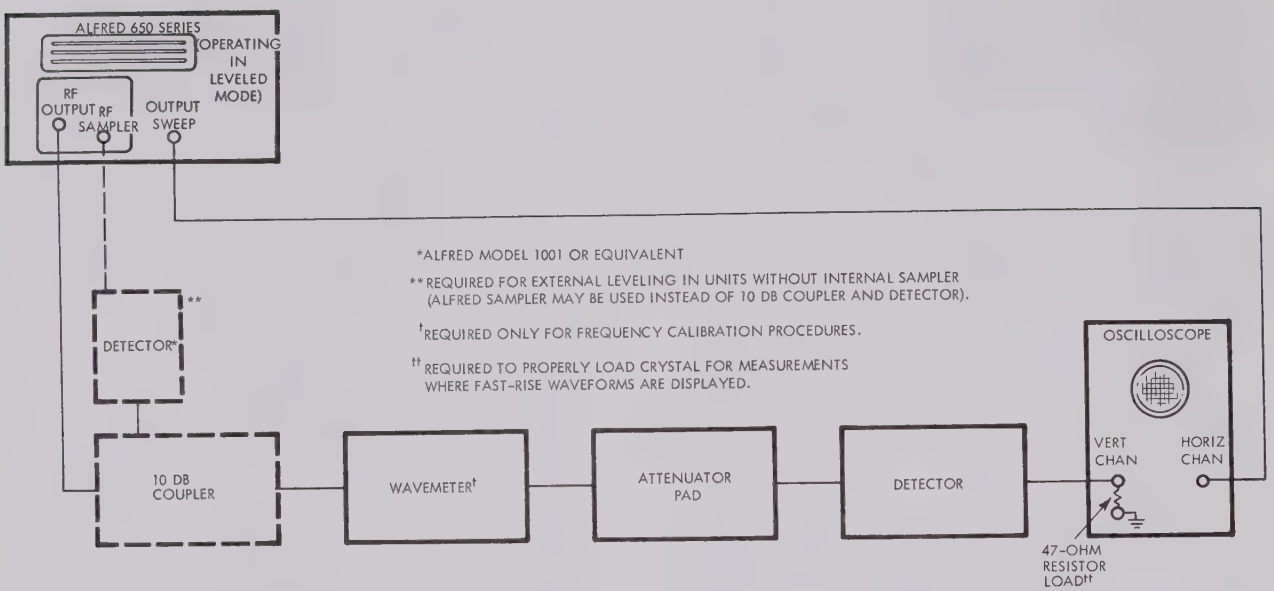


FIGURE 5-3. BASIC RF TEST SET-UP

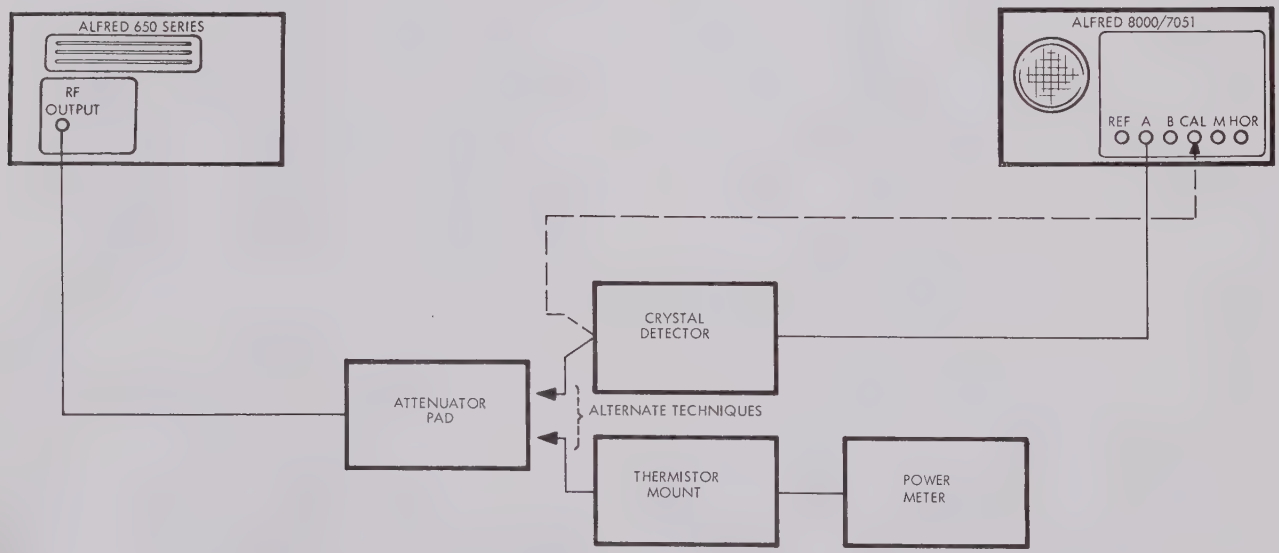


FIGURE 5-4. POWER CALIBRATION TEST SET-UP

properly set, try substituting a different resistance value for R14. A larger resistance value at R14 will tend to increase the sampler output level, thereby moving the full-band-leveling setting of the POWER LEVEL control in the CW direction.

5.5 PARTS REPLACEMENT.

5.5.1 REPLACING THE BWO TUBE. Refer to Paragraphs 5.7.1 and 5.7.2 of the Model 650 Instruction Manual. After the tube is replaced, adjust operating voltages as directed in Paragraph 5.7.5 of the Model 650 Instruction Manual. Then perform final frequency calibration in accordance with Paragraph 5.3.3 of this manual. It is not necessary to replace the time meter after BWO replacement. (No time meter is provided on units having a BWO tube with 1-year warranty.)

NOTE: Always retain the manufacturer's data sheet for the new tube for future reference, by placing it in the envelope at the rear of this manual.

5.5.2 REPLACING INDIVIDUAL CIRCUIT COMPONENTS. Refer to Figures 5-1 and 5-2 of this manual for the locations of circuit boards and major rf components. Parts on all PC boards are identified by silkscreened reference designators. These parts are also shown on the simplified schematics (Figures 4-3 and 4-4) and the overall schematics in Section 7. The proper soldering techniques for parts replacement are given in Paragraph 5.8 of the Model 650 Instruction Manual.

SECTION 6 – PARTS LIST

LIST OF ASSEMBLIES

Circuit Reference	Alfred Part No.	Description	Schematic
		Plug-in Chassis	C900774
A11	950621	Leveler/Amplifier PC Board	C900730
A12		Elevated Supply PC Board	
	951917	(S/N 1011 & above in Models 651 thru 653-S1 or S2 S/N 776 & above in Models 653-655 S/N 371 & above in Models 656-659 except S/N 776 & above in Model 657K)	C907377
	901488	("Later" production below; Serial Numbers shown above)†	C900869
	950620	("Early" production, well below S/N 766 in Units < 12.4 GHz;† "Early" production, well below S/N 371 in Units > 12.4 GHz)†	C900729
A13×	×	Diode Shaper PC Board	C900713
A25	950278	Cathode Supply DC Feedback Board Assy	××C900774

x Refer to Table 7-1 on apron of Schematic C900713.
xx Included on Schematic listed.
t Refer to PC board for positive identification of Assy No.

PLUG-IN CHASSIS

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE†† MFR. FSC NO.	TRUE MFR. PART NO.
		INDICATORS		
DS1	126-11	Lamp, clear, 110 v (UNLEVELED WHEN LIT)	72765	116-303
		CONNECTORS, Jacks		
J1 and J2	133-62	PC plug-in	81212	KZ 105
J3	131-UG-1094	BNC, panel mount (AM EXT INPUT)	94375	UG 1094 U
J4	131-UG-1094	BNC, panel mount (RF SAMPLER INPUT)	94375	UG 1094/U
J5	133-77	Telephone (FREQ. STAB. INPUT)	82389	13-B
		METERS, Elapsed Time		
M1**	87-3	Minichron cartridge	03782	87-3
		CONNECTORS, Plugs		
P1 thru P5		Not used		
P6 and P7	133-71	16 pin, male	74868	26-159-16
		RESISTORS		
R1 thru R6		Not used		
R7	41-100K	Fixed, comp., 100K, 1/2 w, 10%	01121	EB 1041
R8**	56-69.8K	Fixed, met. film, 69.8K, 1/2 w, 1%	19701	MF-7C-TO-69.8K
R9	71-123	Variable, 2.5K, (EXT. SAMP. SENS.)	71450	70-LT-2.5K
R10	(102-134) Part of S2)	Variable, 1K, (POWER LEVEL)	(03782)	(102-134)
R11	71-101	Variable, 250 Ω (MIN. PWR. LEVEL)	71450	BJ 49642
R12	41-330 Ω	Fixed, comp., 330 Ω, 1/2 w, 10%	01121	EB 3311
R13***	71-122	Variable, 2.5K (INT. SAMP. SENS.)	71450	70-LT-2.5K
R14*		Factory Selected Value		
R15	62-1	Fixed, W.W., 10K, 10 w, 5%	35434	C10-10K-T5
R16* and R17*		Factory Selected Value		

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE†† MFR. FSC NO.	TRUE MFR. PART NO.
		SWITCHES		
S1***	102-136	Slide, DPST (INT-EXT Lev)	76854	399278-278
S2	102-134 (WR10)	Rotary (LEVELED-UNLEVELED)	71450	211ND-45NS
		TEST POINTS		
TP21 thru TP23	133-28	Tip jack, red	74970	105-802
		SOCKET, Meter		
XM1***	122-2	Type 3AG, Snap-in	75915	357001

A25 CATHODE SUPPLY DC FEEDBACK BOARD (Assy. 950278)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE†† MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A25C1	12-30	Capacitor, fixed, ceramic, 1.5 pf 6 KV	56289	60-GA-V15
		RESISTORS		
A25R1 thru A25R6	52-464K	Resistor, fixed, MF, 464K, 1 w, 1%	19701	MFS-1-T2-464K

* Factory Select Value
** Not used in Plug-in with B/O having 1 year warranty
*** Used only in Plug-ins having internal sampling
†† See page 6-4 for cross reference list of Federal Manufacturer's Codes.

A11 LEVELER AMPLIFIER PC BOARD (Assy. 950621)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A11C1 and A11C2	12-34	Fixed, ceramic, .1 µf, 100 v	91418	BT 010
A11C3*	12-2 or	Fixed, ceramic, .011 µf, 600 v	91418	JL-X5R-102K
	12-31	Fixed, ceramic, .022 µf, 500 v	56289	5GA-S25
		DIODES		
A11CR1 and A11CR2	81-27	1N625		1N655
		TRANSISTORS		
A11Q1	81-113	2N4956 NS7301 SP9965	07263	2N4956
A11Q2	81-114	2N3638A 2N3250	07263	2N3638A
A11Q3	81-73	2N706		2N706
A11Q4	81-72	2N699		2N699
		RESISTORS		
A11R1	71-102	Variable, 100 Ω, 1, 2 w, 10%	01121	EB 1011
A11R2	41-100 Ω	Fixed, comp., 100 Ω, 1/2 w, 10%	01121	EB 1011
A11R3	41-6.8K	Fixed, comp., 6.8K, 1/2 w, 10%	01121	EB 6821
A11R4	41-1.2K	Fixed, comp., 1.2K, 1/2 w, 10%	01121	EB 1221
A11R5	41-560 Ω	Fixed, comp., 560 Ω, 1, 2 w, 10%	01121	EB 5611
A11R6	(41-100 Ω)	Same as A11R2	(01121)	(EB 1011)
A11R7	41-1K	Fixed, comp., 1K, 1 2 w, 10%	01121	EB 1021
A11R8	41-10K	Fixed, comp., 10K, 1/2 w, 10%	01121	EB 1031
A11R9	41-470 Ω	Fixed, comp., 470 Ω, 1/2 w, 10%	01121	EB 4711
A11R10	41-2.2K	Fixed, comp., 2.2K, 1/2 w, 10%	01121	EB 2221
A11R11	41-3.3K	Fixed, comp., 3.3K, 1, 2 w, 10%	01121	EB 3321
A11R12	(41-10K)	Same as A11R8	(01121)	(EB 1031)
A11R13	41-56K	Fixed, comp., 56K, 1/2 w, 10%	01121	EB 5631
A11R14 and A11R15	41-1M	Fixed, comp., 1M, 1/2 w, 10%	01121	EB 1051

A12 ELEVATED SUPPLY PC BOARD **

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
**Assy. 951917: S/N 1011 & above in Models 651 thru 653-S1 or S2 S/N 776 & above in Models 653-655 S/N 371 & above in Models 656-659 except S/N 776 & above in Model 657K Assy. 901488: "Later" production below Serial Numbers shown above† "Early" production below S/N 776 in units < 12.4 GHz; "Early" production below S/N 371 in units > 12.4 GHz†				
		CAPACITORS		
A12C1	12-28	Fixed, ceramic, .001µf, 6Kv	71590	DD60-102
A12C2		Not used (Assy. 951917)		
	11-2	Fixed, ceramic, 24 pf, 600 v (Assy. 901488)	72136	CM-15E-240-J
	12-1	Fixed, ceramic, 15 pf, 600 v (Assy. 950620)	71982	831-000-U2J0-150J
A12C3 and A12C4		Not used (Assy. 951917)		
	12-3	Fixed, ceramic, .01 µf, 500 v (Assy. 901488 & 950620)	71590	DD-1032
		DIODES		
A12CR1	81-20	1N4385 (S/N 758 & up <12.4 GHz)	76433	1N4385
	81-41	(S/N 291 & up >12.4 GHz)		
	81-41	1N459 (S/N 757 & below <12.4 GHz) (S/N 290 & below >12.4 GHz)		
A12CR2		Not used (Assy. 951917)		
	81-41	1N459 (Assy. 901488 & 950620)	07263	1N459
A12CR3	(81-20)	Same as A12CR1	(76433)	(1N4385)
A12CR4		Not used (Assy. 951917)		
	81-41	1N459 (Assy. 901488 & 950620)	76433	1N4385
A12CR5 and A12CR6		Not used (Assy. 951917)		
	81-156	Zener, MZ 1000-17 (Assy. 901488)	04713	MZ 1000-17
A12CR7	81-206	1N4737A (Assy. 951917) Not used (Assy. 901488 & 950620)	04713	1N4737A

A12 ELEVATED SUPPLY PC BOARD (Con'd)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		INDUCTORS		
A12L1	92-22	Choke, RF, 33 µhy	71895	1537-52
		TRANSISTORS		
A12Q1	81-239	2N2405 (Assy. 951917)	07029	2N2405
		2N699 (Assy. 901488 & 950620)	96214	2N699
		RESISTORS		
A12R1	51-150K	Fixed, dep. carb., 150K, 150K, 1/2 w, 5%	73445	E-009-AB/B-150K
A12R2*		Factory Select (See Addendum A)		
A12R3		Not used (Assy. 951917)		
	46-1K	Fixed, comp., 1K, 2W, 5% (Assy. 901488)	01121	HB 1025
	46-820 Ω	Fixed, comp., 820 Ω, 2 w, 5% (Assy. 950620)	01121	HB 8215
A12R4	50-820 Ω	Fixed, tin oxide, 820 Ω, 2 w, 2% (Assy. 951917)	16299	C42-1.1K
	35-1.1K	Fixed, met. film, 1.1K, 2 w, 5% (Assy. 901488)	16299	C42-1.1K
	46-750 Ω	Fixed, comp., 750 Ω, 2 w, 5% (Assy. 950620)	01121	HB 7515
A12R5	50-820 Ω	Fixed tin oxide, 820 Ω, 2 w, 2% (Assy. 951917 & 901488)	16299	C42S-820 Ω
	46-750 Ω	Fixed, comp., 750 Ω, 2 w, 5% (Assy. 950620)	01121	HB 7515
A12R6		Not used (Assy. 951917)		
	51-7.5K	Fixed, dep. carb., 7.5K, 1/2 w, 5% (Assy. 901488)	73445	E-009-AB/B-7.5K
	41-1.8K	Fixed, comp., 1.8K, 1/2 w, 10% (Assy. 950620)	01121	EB 1821
A12R7	46-10K	Fixed, comp., 10K, 2 w, 5% (Assy. 951917)	01121	HB 1035
	45-11K	Fixed, comp., 11K, 1 w, 5% (Assy. 901488)	01121	GB 1135
	42-18K	Fixed, comp., 18K, 1 w, 10% (Assy. 950620)	01121	GB 1831
A12R8		Not used (Assy. 951917)		
	51-10 Ω	Fixed, dep. carb., 10 Ω, 1/2 w, 5% (Assy. 901488 & 950620)	73445	E-009-AB/B-10 Ω
A12R9	71-106	Variable, 5K (Assy. 951917)	71450	201-50K
	71-103	Variable, 50K, (Assy. 901488 & 950620)	71450	201-50K
A12R10	56-23.7K	Fixed, met. film, 23.7K, 1/2 w, 1%, (Assy. 951917)	19701	MF-7C-TO-23.7K
	56-237K	Fixed, met. film, 237K, 1/2 w, 1% (Assy. 901488 & 950620)	19701	MF-7C-TO-237K
A12R11		Not used (Assy. 951917)		
	51-8.2K	Fixed, dep. carb., 8.2K, 1/2 w, 5% (Assy. 901488 & 950620)	73445	E-009-AB/B-8.2K
A12R12		Not used		
A12R13	56-10 Ω	Fixed, met. film, 10 Ω, 1/2 w, 1%	19701	MF-7C-TO-10 Ω
A12R14* and A12R15*		Factory Select (See Addendum A)		
A12R16		Not used		
A12R17		Not used (Assy. 951917)		
	51-180K	Fixed, dep. carb., 180K, 1/2 w, 5% (Assy. 901488 & 950620)	73445	E-009-AB/B-180K
A12R18		Not used (Assy. 951917)		
	51-27K	Fixed, dep. carb., 27K, 1/2 w, 2% (Assy. 901488 & 950620)	73445	E-009-AB/B-27K
A12R19	50-820 Ω	Fixed, tin oxide, 820 Ω, 2 w, 2% (Assy. 951917) Not used (Assy. 901488 & 950620)	16299	C42S-820 Ω
		TEST POINTS		
A12TP1 thru A12TP3	133-85	Jack, probe insert	78947	119-4378

*Factory Select

† Refer to PC board being repaired for positive identification of Assy No.

DIODE SHAPER PC BOARD (ASSEMBLY A13; See Table 1-1 for Part Nos.)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		CAPACITORS		
A13C1 thru A13C3	12-34	Capacitor, fixed, ceramic, 0.1 μf, 100 v	91418	BT 010
A13C4	12-22	Capacitor, fixed, ceramic, 100 pf, 500 v	71982	821-X5R-101K
A13C5 and A13C6		Same as A13C1		
		DIODES		
A13CR1 thru A13CR14	81-41	Diode, 1N459	07263	1N459
		TRANSISTORS		
A13Q1 and A13Q2	81-115	Transistor, 2N3565	07263	2N3565
		RESISTORS		
A13R1 thru A13R11		See Table 7-1 on schematic 900713C		
A13R12 thru A13R14		Not used		
A13R15	56-750 Ω	Resistor, fixed, MF, 750 Ω, 1/2 w, 1%	19701	MF-7C-TO-750 Ω
A13R16	56-121 Ω	Resistor, fixed, MF, 121 Ω, 1/2w, 1%	19701	MF-7C-TO-121 Ω
A13R17 thru A13R23	56-100 Ω	Resistor, fixed, MF, 100 Ω, 1/2w, 1%	19701	MF-7C-TO-100 Ω
A13R24	56-80.6 Ω	Resistor, fixed, MF, 80.6 Ω, 1/2w, 1%	19701	MF-7C-TO-80.6 Ω
A13R25	56-1K	Resistor, fixed, MF, 1K, 1/2 w, 1%	19701	MF-7C-TO-1K
A13R26	71-90	Resistor, variable, WW, 200 Ω. 20 turns	21030	79PR200
A13R27	41-1.8K	Resistor, fixed, comp., 1.8K, 1/8 w, 10%	01121	EB 1821
A13R28	71-94	Resistor, variable, WW, 5K, 20 turns	21030	79PR5K
A13R29	41-27K	Resistor, fixed, comp., 27K, 1/2 w, 10%	01121	EB 2731
A13R30	41-10K	Resistor, fixed, comp., 10K, 1/2 w, 10%	01121	EB 1031
A13R31	41-150K	Resistor, fixed, comp., 150K, 1/2 w, 10%	01121	EB 1541

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	TRUE MFR. FSC NO.	TRUE MFR. PART NO.
		BWO TUBE (See Table 1-1)		
		OUTPUT LOW-PASS FILTER AND INTERNAL SAMPLER (As applicable; see Table 1-1)		

FEDERAL SUPPLY CODE FOR TRUE MANUFACTURERS

FMC Number	Full Name and Address of Vendor
00656	Aerovox Corporation, 740 Belleville Ave., New Bedford, Mass.
00686	Film Capacitors, Inc., 100 East 8th Street, Pabsaic, N.J.
00816	Hughes Aircraft Co., Vacuum Div., 500 Superior Ave., Newport Beach, Calif.
00853	Sangamo Electric Co., P.O. Box 128, Pickens, S.C.
00866	Goe Engineering Co., 219-21 S. Mednik Ave., Los Angeles, Calif.
01121	Allen Bradley Co., 136 W. Greenfield Ave., Milwaukee, Wisc.
01281	Pacific Semiconductor Co., 10451 W. Jefferson Blvd., Culver City, Calif.
01456	Microwave Development Laboratories, 87 Crescent Road, Needham Heights, Mass.
01963	Cherry Electrical Products Corp., Box 439, Highland Park, Ill.
02111	Spectrol Electric Corporation, 17070 E. Gale Ave., City of Industry, Calif. 91745
03508	G.E. Semiconductor, Electronics Park, Syracuse, N.Y., 13201
03565	Dayton Electronic Products Co., 117 E. Helena St., Dayton, Ohio
03782	Alfred Electronics, 3176 Porter Drive, Palo Alto, California 94304
04009	Arrow-Hart, & Hegeman Elec. Co., 113 Hawthorne St., Hartford, Conn.
04713	Motorola Semiconductor Products, Inc., P.O. Box 955, Phoenix, Arizona
05783	Stewart Engineering Co., 467 Bean Creek Rd., Santa Cruz, Calif.
05820	Wakefield Engineering Inc., 139-T Foundry St., Wakefield, Mass.
06049	Topaz, 3802 Houston, San Diego, California 92110
06555	Beede Electrical Instrument Co., Inc., Penacock, N.H.
06980	Varian, 611 Hansen Way, Palo Alto, Calif. (BWO)
07029	Radio Corp. of America, Electronic Components & Devices, 415 S. 5th St. Harrison, N.J.
07137	Transistor Electronics Corp., Box 6191, Minneapolis, Minn.
07263	Fairchild Semiconductor, 545 Whisman Rd., Box 880, Mountain View, Calif.
08806	General Electric Corp., Min. Lamp Dept., Nela Park, Cleveland, Ohio
09022	Cornell-Dubilier, 50 Paris St., Newark, N.J. (Mica Caps)
09023	Cornell-Dubilier, 50 Paris St., Newark, N.J. (Electrolytic Caps)
09297	CP Electronics Inc., Columbus, Ind.
11312	Microwave Electronics Div. of Teledyne, 3165 Porter Drive, Palo Alto, Calif.
12060	Diodes, Inc., 9261 Independence Ave., Chatsworth, Calif.
12122	Astrodyne, Inc., 2nd Ave., NW. Ind. Park, Burlington, Mass. 01803
12360	Albany Products, 351 Connecticut Ave., South Norwalk, Conn.
12697	Clarostat Mfg. Co., Washington St., Dover, N.H.
13664	Workman Elec. Prod. Inc., Packing House Rd., Sarasota, Florida 33578
13862	Alasco Rubber & Plastic Corp., 839 Malcom Rd., Burlingame, Calif.
14026	Spatron, Inc., 715 S. Raymond Ave., Alhambra, California 91803
14433	International Telephone & Telegraph, 3301 Electronic Way, W. Palm Beach, Florida
14482	Watkins-Johnson Co., 3333 Hillview, Palo Alto, California
15582	Bay City Screw & Bolt Co., 601 Industrial Way, San Carlos, Calif.
15818	Amelco, 1300 Terra Bella, Mt. View, Calif. 94042
16299	Corning Glass Works, Electronic Products Div., 3906 Electronics Dr., Raleigh, N.C.
16741	Triad Dist. Div. (Litton Ind.) 305 N. Briant St., Huntington, Ind.
17474	Tranex, Inc., 1599 Stierlin Rd., Mountain View, California
17545	Atlantic Semiconductors, Inc., 905 Mattison Ave., Asburg Park, N.J. 07712
17920	Wornecke Electron Tubes, 175 W. Oakton St., Des Plaines, Ill.
18489	Reliable Capacitors Co., 14716 Arminta St., Van Nuys, Calif.
18915	Birtcher Corp., The Industrial Div., 745 S. Monterey Pass Rd., Monterey Park, Calif.
19701	Electra Mfg. Co., 800 North 21, Independence, Kansas
20286	Daytron, Inc., 1269 Terra Bella, Mountain View, California
20649	Universal Metal Products, 5924 N. Western Ave., Chicago 45, Ill.
21030	Beckman Instrument, Inc., Helipot Div., 2500 Harbor Blvd., Fullerton, California
21743	Conseat Corp., 4164 Greenbush Ave., Sherman Oaks, Calif.
22229	Union Carbide, KEMET Elect. Div., Mountain View, California
23880	Standford Applied Engineering, 340 Martan Ave., Santa Clara, Calif.
24220	Gowanda, 179 Broadway Rd., Gowanda, N.Y.
24796	Parelco, Inc., 26181 Avenida Aevoprierto, San Juan Capistrano, California
27014	National Semi-Conductor Corp., 2950 San Ysidro Way, Santa Clara, Calif.
28480	Hewlett-Packard, Paeco Div., 3215 Porter Drive, Palo Alto, California
31918	International Electronics Exchange, 6529 Cambridge St., Minneapolis, Minn. 55426
33173	General Electric Corporation., Tube Dept., 316 E. Ninth St., Owenboro, Ky.
35434	Lectrohm, Inc., 5560 Northwest Hwy., Chicago, Ill.
37942	Mallory Capacitor Co., Div. P.R. Mallory & Co., Inc., 3029 E. Washington St., Indianapolis, Ind.
42190	The Muter Co., 1255 S. Michigan Ave., Chicago 5, Ill.
42498	National Radio Co., Melrose, Mass.
44655	Ohmite Mfg., Co., 3635 W. Howard St., Skokie, Ill.
46384	Penn Engineering, West State St., Doylestown, Penn.
56289	Sprague Electric Co., 91 Marshall St., N. Adams, Mass.
59730	C/O Thomas & Betts Co., 645 Phelps St., San Francisco, California
70309	Allied Control Co., Inc., 2 East End Ave., New York, New York
70563	Amperite Co., Inc., 600 Palisade Ave., New Jersey
70903	Belden Mfg. Co., Box 5070-A, Chicago, Ill. 60644
71436	Chicago Condenser Corporation, 3253 Armitage Ave., Chicago, Ill. 60647
71450	CTS Corp., 1172 W. Beardsley, Elkhart, Ind.
71590	Centralab, Electronics Div., Globe Union, 934 Keefe Ave., Milwaukee, Wisconsin
71785	Cinch Mfg. Co., 1026 S. Homan Ave., Chicago 24, Ill.
71895	Delavan Mfg. Co., Electro-Sonics Div., West Des Moines, Iowa
71982	Erie Technological Products, Inc., 644 W. 12th St., Erie, Penn.
72012	M. Ducommun Mfg. Co., 580 Fifth Ave., New York , New York 90036
72136	Electro Motive Mfg. Co., Inc., S. Park & John Streets, Williamantic, Conn.
72765	Drake Mfg. Co., 4626 N. Olcott Avenue, Harwood Heights, N.Y. 60656
72983	Stancor Electronics (Essex Wire Corp.) 3501 W. Addison St., Chicago, Ill.
73293	Hughes Aircraft Co., Elec. Comp., Div., 500 Superior Ave., Newport Beach, Calif.
73445	Amperex Electronic Corporation, Box 418, 230 Duffy Ave., Hicksville, N.Y.
73899	JFD Elect. Co., Comp. Div., 15th Ave., at 62nd St., Brooklyn, N.Y.
74542	Hoyt Electrical Inst. Works, Inc., 42 Carleston St., Cambridge, Mass.
74868	Amphenol Corp., Connector Div., 1830 S. 54th Ave., Chicago, Ill.
74970	The E.F. Johnson Co., 1923 10th Ave., S.W. Waseca, Minn.
75376	Kurz Kasch, 1417 S. Broadway, Dayton, Ohio
75382	Kulka Electric Corp., 520 S. Fulton Ave., Mt. Vernon, N.Y.
75042	IRC, Inc., 401 N. Broad St., Philadelphia, Penn.
75497	Lamson & Sessions, 5002 Tiedeman Rd., Cleveland, Ohio
75915	Littlefuse, Inc., 800 E. Northwest Hwy., Des Plaines, Ill.
76433	General Instrument Corp., 65 Gouverneur, Newark, N.J.
76487	James Millen Mfg. Co., Inc., 150 Exchange St., Malden, Mass.
76854	Oak Mfg. Co., Crystal Lake, Ill.
77342	Potter & Brumfield, Div., American Machine & Foundry Co., 1200 E. Broadway, Princeton, Ind.
77557	Reliable Spring & Wire Forms Co., 3167 Fulton Rd., Cleveland, Ohio
78553	Tinnerman Co., Dept. 16-T, P.O. Box 6688, Cleveland, Ohio
78947	Ucinite Corporation, 459 Watertown St., Newtonville, Mass. 02160
79493	J.W. Miller Co., 5915 S. Main St., Los Angeles, Calif. 90003
80294	Bourns, Inc., 1200 Columbia Ave., Riverside, California 92507
81073	Grayhill, Inc., 569 Hillgrove Ave., La Grange, Ill.
81312	Winchester Electronics, Inc., Div. Litton Industries, 19 Willard Rd., Norwalk, Conn.
82389	Switchcraft, Inc., 5555 N. Elston Ave., Chicago 30, Ill.
83186	Victory Engineering, 128 Springfield Ave., Springfield, New Jersey
83701	Electronic Devices, Inc., 21 Grey Oaks Ave., Yonkers, N.Y.
88245	USECO, Div. of Litton Industries, 13536 Saticoy St., Van Nuys, Calif.
89536	John Fluke Mfg. Co., Inc., P.O. Box 7428, Seattle, Wash.
91278	Stoesser Tool & Die, 3366 Fayette Dr., Mountain View, California
91418	Radio Materials Co., 4242 W. Bryn Mawr Ave., Chicago 46, Ill.
91637	Dale Electronics, Inc., (Subs. Lionel Corp.), Box 609, 1342 - 28th St., Columbus, Nebr.
91737	Gremar Mfg. Co., Wakefield, Mass.
91755	Harrison & Bonini, 1122 Harrison St., San Francisco, California
91827	K & F Tool Die & Mfg. , Inc., 1203 Dell Ave., Campbell, California
93332	Sylvania Electric Products, Inc., Semiconductor Div., 100 Sylvan Rd., Woburn, Mass.
93389	Proto Stamping, Washington & Santa Fe, Los Angeles 54, Calif.
94144	Raytheon, 465 Centre St., Quincy, Mass. 02164
94375	Automatic Metal Products Corp., 323 Berry St., Brooklyn 11, N.Y.
95263	Leecraft Mfg. Co., Inc., 44-35 - 21st St., Dept. E., Long Island City, N.Y.
95354	Methode Electronics, Inc., 7447 W. Wilson Ave., Chicago, Ill.
95987	Weckesser Co., Inc., 4444 W. Irving Park, Chicago, Ill.
96214	Texas Instruments, Inc., Semiconductor-Components Div., Box 5012, Dallas, Texas
96791	Borg Electronics, Div., Amphenol-Borg Electronics Corp., 120 S. Main St., Janesville, Wisc.
97464	Industrial Retaining Ring Co., 57 Cordier St., Irvington, N.J.
99120	Plastic Capacitors, Inc., 2620 N. Clybourn Ave., Chicago, Ill.
99313	Varian, 611 Hansen Way, Palo Alto, California (BWO)
99942	Hoffman Electronics Corp., Semiconductor Div., Box 471, El Monte, California

ADDITIONAL NUMBERS

00929	Microlab/FXR, 10 Micralab Rd., Livingston, N.J.
02114	Ferroxcube Corp. of America, Mt. Marion Rd., Saugerties, N.Y. 12477
02116	Wheelock Signals Inc., 273 Branchport Ave., Long Branch, N.J. 07440
03888	Pyrofilm, 3 Saddleroad, Cedar Knolls, N.J. 07927
04773	Automatic Electric Co., Wolf Rd. Northlake, Ill. 60164
11870	Melabs, Inc., 3300 Hillview, Palo Alto, Calif. 94304
12598	RLC Electronics, Inc., 25 Martin Pl., Port Chester, N.Y. 10573
13175	Electro-Mechanical Corp., 701 S. Elmer Ave., Sayre, Pa. 18840
18741	High Vacuum Electronics, Inc., 538 Mission St., So. Pasadena, Calif. 91030
23095	Aztec Electronics, Inc., 163 Liberty Ave., Anaheim, Calif. 92801
24931	Spec. Connector Co., 3560 Madison Ave., Indianapolis, Ind. 46227
26851	Compac Eng. Co., 810 East St., Hollister, Calif. 95023
70318	Allmetal Screw Products Co. Inc., 821 Stewart Ave., Garden City, N.Y.
71707	Cato Coil Co. Inc., Box B, Edgewood Station, Providence, R.I.
73559	Carling Electric Inc., 505 New Park Ave., West Hartford, Conn. 06110
80080	Litton, San Carlos, Calif. (Vac. Tube Div.)
82227	Haydon, A.W., Co., 232 N. Elm St., Waterbury, Conn. 06720
89110	AMP, Inc., 155 Park St., Elizabethtown, Pa.
91836	Kings Elec., 40 Marblehead Rd., Tuckahoe, N.Y. 11223
94696	Magnecraft Electric Co., 5579 N. Lynch Rd., Chicago, Ill. 60630
95348	Gordos Corp., 250 Glenwood Ave., Bloomfield, N.J. 07003
95712	Dage, Franklin, Ind.
98003	Neilson Hdwr. Corp., 770 Weathersfield Ave., Hartford, Conn.
99779	Barnes Dev. Co., 213 W. Baltimore Pike, Lansdowne, Pa. 19050

SECTION 7

SCHEMATIC DIAGRAMS

Schematics are included in the following order:

OVERALL CHASSIS SCHEMATIC	(C900740)	
LEVELER-AMPLIFIER PC BOARD A11	(900730C)	
ELEVATED SUPPLY PC BOARD A12	(C907377:	S/N 1011 & above in Models 651 thru 653-S1 or S2 S/N 776 & above in Models 653-655 S/N 371 & above in Models 656-659 except S/N 776 & above in Model 657K)
	(C900869:	Units having serial numbers below the above)
DIODE SHAPER PC BOARD A13	(900713C)	

SYM	DESCRIPTION	NO.	DATE	BY
A-E	INCORP ECO 12708, 12768, 12834, 12760A,	—	11-1-65	[illegible]
F	R8 WAS FACTORY SELECTED	12936	2-21-66	MS
G	ADDED R17. REVISED CKT S/N 11-UP	12980	9-7-66	MS
H	DELETED R17 REVISED CKT S/N 351-UP	12980A	3-7-67	MS
I	REPLACED 901492 WITH 901488. S/N 431-UP	13118A	3-8-67	MS
J	ADDED JUMPER BETWEEN A12-4 & 5 SERIAL 711 & UP	13245	10-28-67	CWK R.R.T.
K	ADDED CONNECTION BETWEEN A12-13 & A12-16 S/N: 711 & UP	13257	6 NOV 67	C.W.K. R.R.T.

ELEVATED SUPPLY A12 900869C

1 GRID DRIVER
2 -100V
3 ANODE FEEDBACK
4 ANODE
5 ANODE
6 HEATER (-)
7 BWO (Black)
8 HEATER (+)
9 BWO (Brown)
10 CATHODE
11 BWO (Yellow)
12 ΦLINE
13
14
15 GRID
16 BWO (Green)
17 BWO (Orange)
18 COLLECTOR
19 HELIX
20 BWO
21 +100V
22 GND 5
23 PULSE INPUT
24 GND 7
25 HELIX

D7 SWEEP OSCILLATOR
ANODE
ANODE FEEDBACK
Φ
-100V
DRIVER
SEE NOTE 3

TP23 GRID
TP22 HELIX
TP21 COLL.

J5 FREQ. STABILIZING INPUT
R15 10K

D6 SWEEP OSCILLATOR

R8 * 69.8K 1%
M1 * ELAPSED TIME METER

R12 * 330 (NOMINAL)

J3 INPUT AM. EXT.

R10 1K RF OUTPUT PWR LEVEL
R11 250 MIN. PWR. LEVEL

A25 HIGH VOLTAGE FEEDBACK BOARD
R1 464K 1W, 1%
R2 464K 1W, 1%
R3 464K 1W, 1%
R4 464K 1W, 1%
R5 464K 1W, 1%
R6 464K 1W, 1%
C1 1.5 PF - 6KV
J4 RF SAMPLER INPUT

TO SAMPLER **
** R13 2.5K INTERNAL SAMP. SEN.
R14** *
** S1 RF SAMPLER
INT.
EXT.
R9 2.5K RF SAMPLER SENSITIVITY
R16 *
Connected in units without internal sampling

LEVELED
UNLEVELED
S2 RF OUTPUT
R7 100K

DS1 UNLEVELED WHEN LIT

A13 J1 DIODE SHAPER
A -15V
B -50V
C GND 2
D GND 5
E GND 5
F TO CATHODE SAMPLER R DC FEEDBACK
H +15V
J
K
L

A11 J2 LEVELER AMPLIFIER
A +15V
B SAMPLER INT/EXT. SWITCH
C RF. LEVEL POT
D GND 6 TRAN OSC.
E GND 5
F POWER LEVEL IND.
H +100V
J
K
L -15V

-50V
-15V
+15V
+100V

NOTES:
1. UNLESS OTHERWISE SPECIFIED:
   1A. ALL RESISTOR IN OHMS, 1/2 W, 10%
   1B. ALL CAPACITOR IN MICROFARADS, 500V
   1C. ALL RESISTOR 1% ARE METAL FILM
2. SQUARE (□) DESIGNATES TERMINAL CONNECTION ON ASSY "A12", 901488
3. JUMPER FOR ANODE VOLTAGE GREATER THAN 100 VOLTS.
4. *OPTIONAL, REFER TO ADDENDUM A OF INSTRUCTION MANUAL
5. **INCLUDED ONLY ON UNITS WITH INTERNAL RF SAMPLER (K MODEL NO. SUFFIX)

Revised 10/1/69

ITEM	REQD	PART NO.	DESCRIPTION
			LIST OF MATERIAL

MATERIAL —
MATERIAL STOCK NO. —
FINISH OR TREATMENT —

DRAWN Victor Y. Stern DATE 10-16-14
ENG A. Kahn 1-4-65
PROD Alan D. Anderson 1-11-65
SCALE —

SCHEMATIC PLUG-IN GRID LEVELING

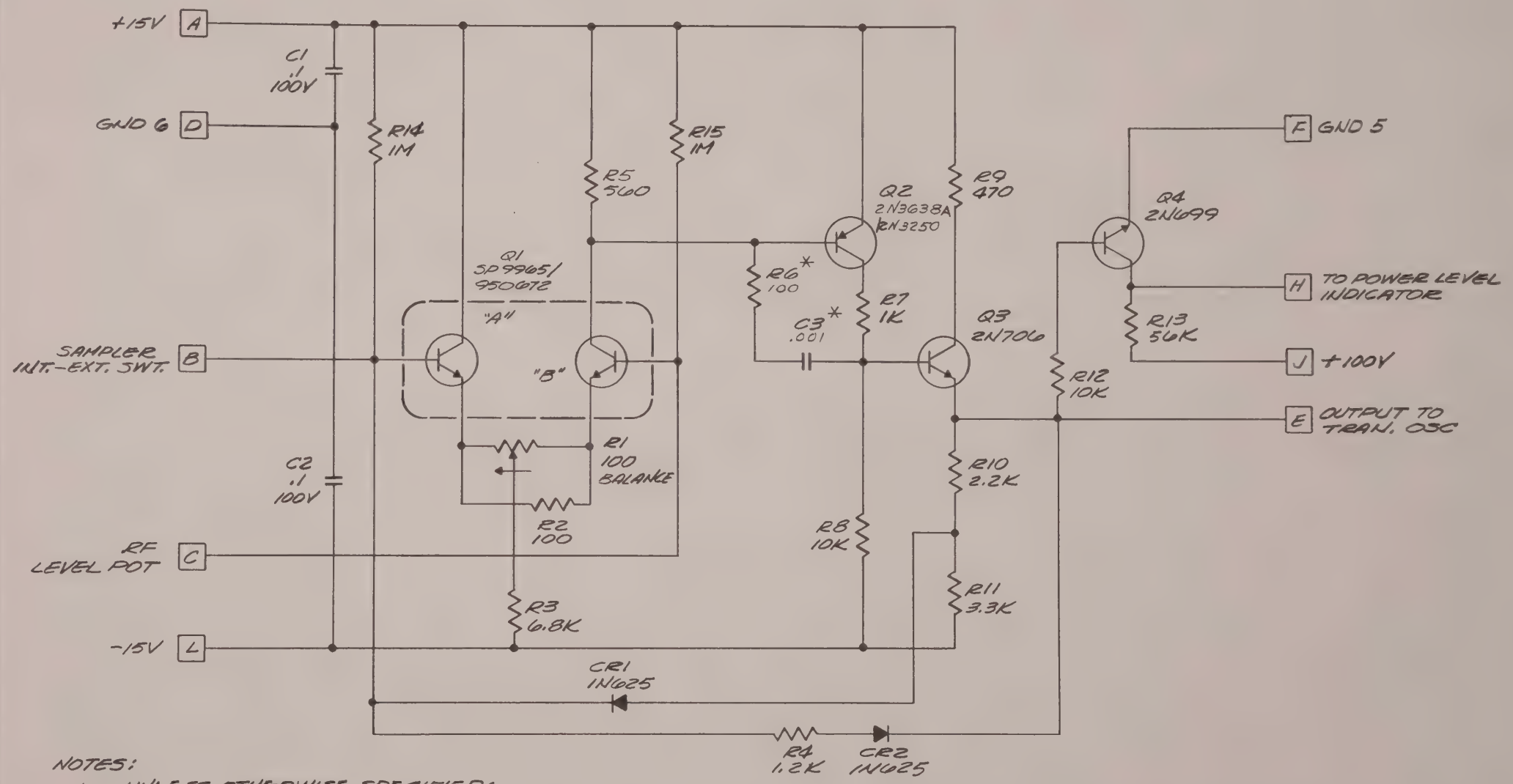
DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005, ANGLE ± ½°
UNLESS INDICATED OTHERWISE

S/N: 711 & UP | 650 KB
NEXT ASSY | USED ON

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

SIZE C | 900740-3 | REV K
SHEET 1 OF 1

SYM	DESCRIPTION	NO.	DATE	BY
A	Q2 WAS 2N3250	12632	2-6-5	cg
B	REMOVED NOTE 4 R6 & C3 MADE FACTOR SEL.	12642	2-15-5	cg



NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   1A. ALL RESISTORS IN OHMS, 1/2W, 10%
   1B. ALL CAPACITORS IN MICROFARADS, 500V
2. SQUARES (□) DESIGNATES PRINTED CIRCUIT CONNECTION ON ASSY "A11", ASSY NO. 950621
3. PREFIX REFERENCE DESIGNATORS BY "A11" (I.E: A11R1, A11Q4)

* FACTORY SELECTED

ITEM	REQD	PART NO.	DESCRIPTION
LIST OF MATERIAL			

S/N 11	6521-34
SER NO. 11 & UP	650
NEXT ASSY	USED ON

MATERIAL —

MATERIAL STOCK NO. —

FINISH OR TREATMENT —

DRAWN	VC Irow	9-13-64
ENG	Jim Johnson	1-4-65
PROD	H Kinne	1-11-65

SCALE —

SCHEMATIC LEVELER AMPLIFIER (GRID LEVEL)

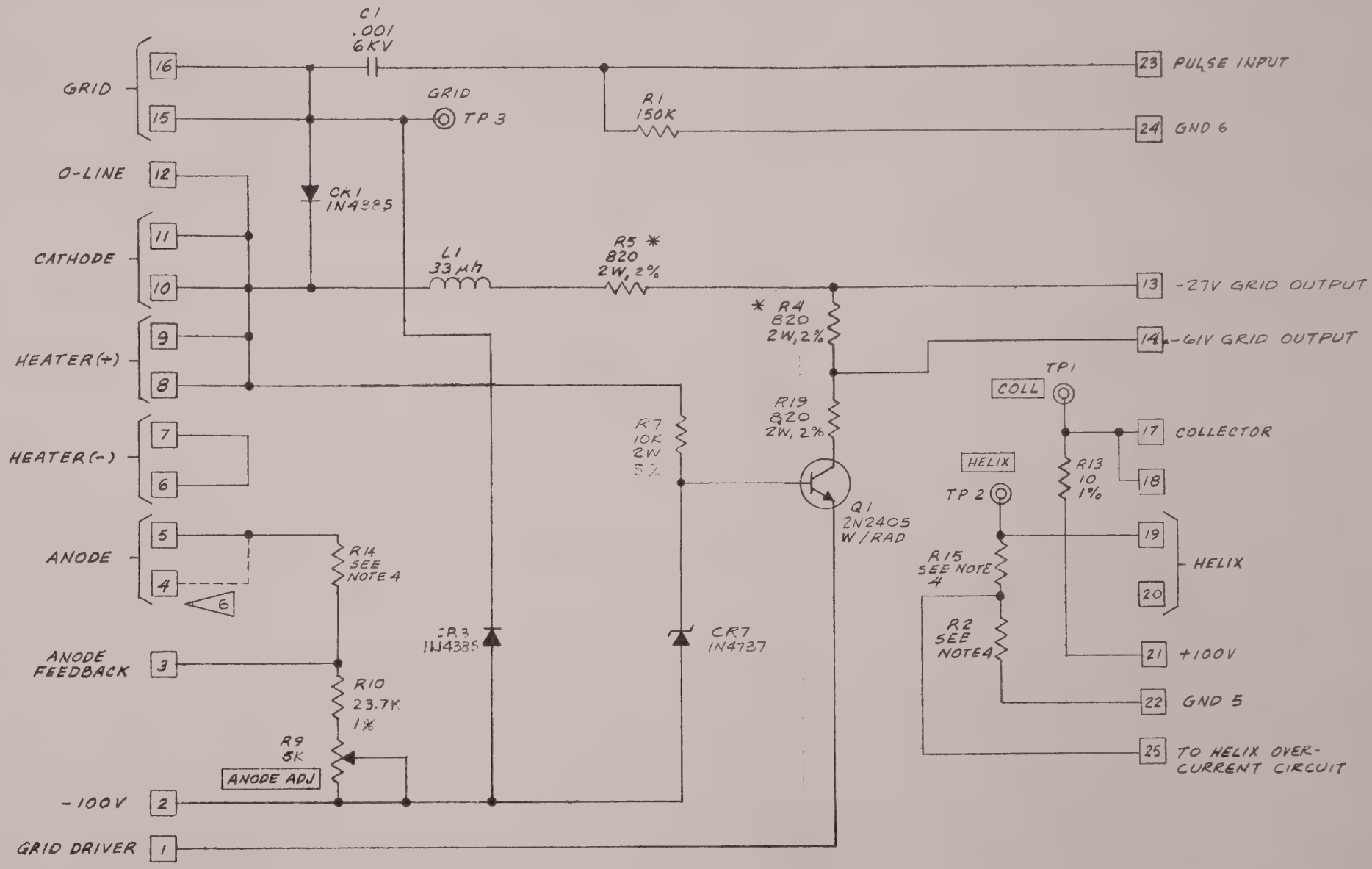
DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005, ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

900730C

SHEET 1 OF 1

SYM	DESCRIPTION	NO.	DATE	BY



REFERENCE DESIGNATIONS		
FIRST	LAST	NOT USED
C1	C1	
CR1	CR7	CR2,4,5,6
L1	L1	
Q1	Q1	
R1	R18	R3,R12,R16 R6,R8,R17 R18 R11

NOTES:

UNLESS OTHERWISE SPECIFIED:

2 SQUARES (□) DESIGNATE TERMINAL CONNECTIONS ON ASSY "A12" ASSEMBLY NO. 951917

3 PREFIX REFERENCE DESIGNATORS BY "A12" (I.E.: A12R1, A12Q1)

4 REFER TO INSTRUCTION MANUAL. (R14 IN K OHMS = $\frac{\text{ANODE VOLTAGE}+5}{3.9}$)

5 ASSY P.C. BD. NUMBER IS 944286

6 ON INSTRUMENTS USING THE ANODE PROTECTION CIRCUIT 951155, THE CONNECTION BETWEEN A12-4 & A12-5 IS BROKEN.

* FACTORY SELECT

1481 & UP	650-6
S/N 776 & UP < 12.4 GHz	650-3
S/N 371 & UP > 12.4 GHz	-1,3-5
S/N 1011 & UP < 12.4 GHz	650-1
951917	650 PLUG-IN
NEXT ASSY	USED ON

ITEM	REQD	PART NO.	DESCRIPTION
LIST OF MATERIAL			

MATERIAL

MATERIAL STOCK NO.

FINISH OR TREATMENT

DRAWN K. BURNS 11/16/67

ENG.

PROD

SCALE

SCHEMATIC ELEVATED SUPPLY

DIMENSIONS ARE IN INCHES
TOL: .XX ± .015 .XXX ± .005 ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

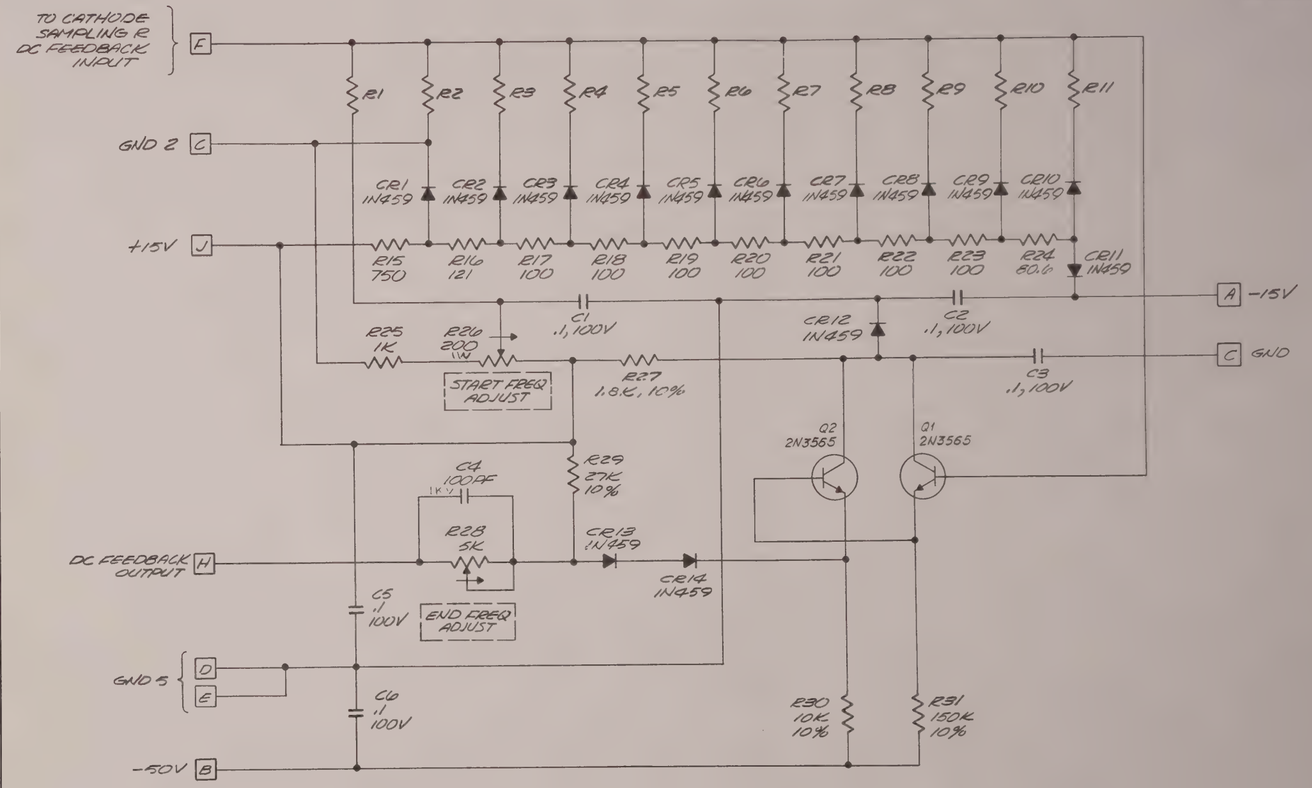
SIZE C | 907377 | REV.

SHEET 1 OF 1

Table of Resistor Values for the Diode Shaper Assembly

Frequency GHz.	6400 Model No.	650 Model No.	Tube Manufacturer	Alfred Tube No.	Diode Shaper PC Board	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
1 to 2	6410 thru 6415	651 651C 651K 651CK	Stewart	112-029	950636	124K	165K	499K	475K	357K	562K	432K	422K	866K	261K	576K
1.4 to 2.5	6410-1 thru 6415-1	651-S1 651C-S1 651K-S1 651CK-S1	Stewart	112-034	950637	107K	340K	442K	576K	887K	412K	464K	1.15M	374K	412K	1.15M
1.7 to 4.2	6420-1 thru 6423-1	652-S5 652C-S5 652K-S5 652CK-S5	Stewart	112-033	950858	178K	102K	280K	261K	205K	187K	210K	154K	147K	137K	162K
2 to 4	6420 thru 6425	652 652C 652K 652CK	Watkins-Johnson	112-095	951877	107K	121K	750K	309K	422K	348K	287K	536K	267K	392K	383K
			Varian	112-015	951601	215K	274K	953K	887K	536K	604K	619K	634K	562K	487K	634K
			Stewart	112-031	950638	133K	124K	383K	332K	340K	280K	301K	267K	232K	221K	232K
3.5 to 6.75	6430-1 thru 6435-1	653-S1 653C-S1 653K-S1 653CK-S1	Stewart	112-035	950640	100K	121K	402K	383K	243K	301K	237K	374K	130K	340K	174K
			Varian	112-016	951602	226K	340K	768K	909K	866K	649K	576K	649K	562K	562K	453K
3.7 to 8.3	6430-2 thru 6433-2	653-S2 653C-S2 653K-S2 653CK-S2	Stewart	112-028	950965	158K	110K	316K	261K	226K	221K	178K	165K	154K	124K	110K
			Varian	112-017	951610	205K	147K	402K	374K	324K	294K	267K	237K	165K	412K	140K
4 - 8	6430 thru 6435	653 653C 653K 653CK	Stewart	112-027	950639	133K	133K	392K	340K	294K	274K	243K	215K	200K	187K	154K
			Varian	112-006	950932	215K	196K	499K	357K	324K	287K	261K	215K	178K	143K	143K
			Watkins-Johnson	112-105	951909	130K	133K	374K	357K	287K	287K	200K	255K	182K	187K	133K
7 to 11	6440 thru 6443	654 654C 654K 654CK	Varian	112-012	950641	187K	866K	976K	1.15M	1.02M	953K	649K	698K	634K	576K	499K
			Watkins-Johnson	112-039	951699	86.6K	576K	806K	549K	866K	442K	665K	523K	324K	619K	422K
7 to 12.4	6440-1 thru 6443-1	654-S1 654C-S1 654K-S1 654CK-S1	Varian	112-012	950647	191K	274K	619K	536K	475K	402K	365K	316K	249K	249K	169K
			Watkins-Johnson	112-039	951603	82.5K	154K	357K	357K	301K	301K	255K	243K	215K	200K	182K
8 to 12.4	6450 thru 6453	655 655C 655K 655CK	Varian	112-013	950642	133K	465K	715K	649K	549K	536K	475K	392K	357K	294K	280K
			Watkins-Johnson	112-038	951604	634K	340K	453K	464K	442K	365K	324K	442K	267K	324K	243K
10 to 15.5	6460	656	Varian	112-014	950643	137K	549K	750K	715K	487K	536K	619K	453K	499K	549K	249K
12.4 to 18	6470 6471	657 657K	Watkins-Johnson	112-109	951910	69.8K	464K	649K	348K	499K	280K	383K	255K	215K	280K	221K
			Varian	112-009	950644	133K	—	1.40M	768K	1.40M	604K	866K	536K	590K	715K	604K
18 to 26.5	6480	658	Watkins-Johnson	112-110	951911	69.8K	464K	643K	475K	422K	332K	309K	332K	226K	237K	191K
			Varian	112-010	950645	150K	1.40M	1.24M	953K	909K	750K	825K	634K	649K	442K	324K
26.5 to 40	6490	659	Watkins-Johnson	112-111	951912	75K	301K	442K	340K	442K	324K	316K	287K	191K	280K	154K
			Varian	112-011	950646	110K	464K	634K	619K	549K	475K	442K	392K	294K	357K	243K

SYM	DESCRIPTION	NO	DATE	BY
A	Q1 & Q2 REPLACED Q1A+Q1B S/N 30 & UP	12700	4-15-65	MN
B	SCHEMATIC ERROR R27 WAS SHOWN AS 1.5K	13772	7-14-66	pfc



NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   1A. ALL RESISTORS IN OHMS, 1/2W, 1% METAL FILM
   1B. ALL CAPACITORS IN MICROFARADS
2. REFER TO INSTRUCTION MANUAL FOR SPECIFIC VALUE OF R1 THRU R11 FOR THE PARTICULAR MODEL INVOLVED
3. SQUARES (□) DESIGNATE PRINTED CIRCUIT CONNECTION ON ASSY NO. 950---
4. PREFIX REFERENCE DESIGNATORS BY "A13" (I.E: A13R1, A13Q2)

ITEM	REQD	PART NO	DESCRIPTION

LIST OF MATERIAL

MATERIAL	DRAWN A. Fox	DATE 11-9-64
	ENG Ken Schmitt	12-4-65
MATERIAL STOCK NO.	PROD W. Kelsoe	12-11-65
FINISH OR TREATMENT	SCALE	

SCHEMATIC DIODE SHAPER

DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005, ANGLE ± ½°
UNLESS INDICATED OTHERWISE

S/N 11-UP	650
NEXT ASSY	USED ON

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

900713C

SHEET / OF /

ALFRED

Tube Warranty and Replacement Procedure

TUBE REPLACEMENT

All TWT and BWO tubes furnished in ALFRED instruments are available from ALFRED ELECTRONICS for either warranty or out-of-warranty replacements. Current prices are given on the Replacement Tube Price List.

TUBE WARRANTY

The following warranties are applicable to tubes used in catalog instruments only. For the warranty applicable to tubes used or for use in special or modified instruments, please check with the factory. All tube warranties are from date of shipment by ALFRED.

WARRANTY FOR TWT AND VTM

Tubes are warranted unconditionally against defects in workmanship, materials, and construction within the period shown in Column A and the number of heater hours shown in Column B. To supplement the unconditional warranty, the tubes are warranted on a pro-rata basis for the rated number of heater hours shown in Column C or for one year, both computed from the date of original shipment by ALFRED, whichever expires first. The pro-rated adjustment will be based on the current list price of the tube and the unused percentage of heater hours (Column C) or one-year time period, whichever results in lesser credit.

Warranty Condition*	Tube Type	Applicable Tube Group or Alfred Tube Part No. Series	A Mo.	B Hours	C Hours
WC2	VTM	112-001 and 112-003	2	100	1000
WC3	TWT	10 and 20 mw output except WC4 tubes	12	500	2000
WC4	TWT	112-040 and 112-047	12	2000	-
WC5	TWT	1 watt output except WC6 and WC7 tubes	12	1500	-
WC6	TWT	112-046, 112-065, & 112-072	12	1000	-
WC7	TWT	112-057, 112-080, & 112-081	12	250	1000
WC8	TWT	2 to 10 watt output except WC9 tubes	12	75	500
WC9	TWT	112-055	2	50	500

* WC# denotes the corresponding warranty period(s) shown in the right-hand column(s) and is used for cross-reference to this warranty statement from other documents.

WARRANTY FOR ALL BWO TUBES

Tubes are warranted unconditionally against defects in workmanship, materials, and construction within the period shown below, without regard to the number of heater hours used.

Warranty Condition*	Tube Type	Warranty
WC10	BWO	Warranted unconditionally for one (1) year.

WARRANTY CONDITIONS APPLY ONLY TO TUBES LISTED ABOVE WHICH ARE USED IN ALFRED CATALOG INSTRUMENTS.

This warranty applies only to tubes sold after July 1, 1969.

TUBE SERVICE REPORT

TO OBTAIN WARRANTY CREDIT THE TUBE SERVICE REPORT MUST BE COMPLETED AND RETURNED WITH THE TUBE.

RETURN PROCEDURE

In case a tube or instrument fails, please contact the factory or your local sales representative for advice or authorization to return either the tube or the instrument to the factory. NO TUBE OR INSTRUMENT WILL BE ACCEPTED FOR REPAIR OR CREDIT ADJUSTMENT WITHOUT WRITTEN AUTHORIZATION AND ACCOMPANYING SERVICE REPORT.

When the authorization is received, pack the tube in a rigid container (use original carton if available) at least 4" larger than the tube in each dimension. Wrap the tube with 1/4" of soft padding material and heavy kraft paper before placing in container. Pack at least 2" of resilient dunnage such as rubberized hair, foam, or similar shock absorbing material completely around the tube. Mark the container "FRAGILE" and ship PREPAID via air freight, air express or rail express. Do not ship via parcel post or air parcel post since experience has shown that fragile items are more apt to be damaged when shipped via these methods.

Use similar wrapping, packing and shipping provisions for an instrument. At least 6" of rubberized hair (or equivalent shock absorbing material) is required for an instrument.

IN-WARRANTY FAILURE - BWO AND VTM TUBES

BWO and VTM tubes which fail in warranty will be replaced with a new tube. In case a tube fails, please issue a purchase order for a new tube at the tube list price and return the defective tube. Warranty credit will be issued and deducted from the price, subject to tube manufacturer's verification that failure was caused by tube malfunction. To qualify for maximum credit, it is essential that the defective tube be properly packed and returned within 30 days after failure.

REPAIRABLE OR IN-WARRANTY FAILURE - TW TUBES

If the returned tube is found to be repairable, the user will be asked to issue a purchase order for repair charges determined by the original tube manufacturer. In general, the repair will be at no cost if the tube is in warranty and there is no evidence of misuse or abnormal conditions of operation.

WARRANTY CREDIT

Any applicable credit allowed under the terms of this warranty applies only toward the purchase of a replacement tube from ALFRED ELECTRONICS. Cash settlements will not be made. In terms of this warranty, a replacement tube must be the same type as that on which credit is allowed. Credit for one tube only may be applied toward the purchase of a single replacement tube. Warranty credit remains in effect for a maximum of six (6) months from date ALFRED ELECTRONICS notifies the customer. All credits will be based on the purchase price of the tube which prevails at the time the order for a replacement tube is received by ALFRED ELECTRONICS.

BWO RF CABLES

RF OUTPUT CABLE MUST ACCOMPANY BWO TUBES returned for warranty credit, repair or replacement. If rf output cable is NOT returned, the cable price is added to the normal BWO repair or replacement charge. For prices see Replacement Tube Price List.

SPECIAL CONDITIONS

If a returned tube or instrument proves not to be defective after test and evaluation at ALFRED ELECTRONICS, the tube or instrument will be returned at the customer's expense.

The final determination as to whether the tube failed in normal operation thereby bringing it under the applicable warranty or whether the tube was misused thereby excluding it from application of the warranty provisions, lies solely with the tube manufacturer.

Data, warranty credit, and prices subject to change without notice.

8/1/69

ALFRED ELECTRONICS

Service Report

Instrument Model _____ Serial No. _____ Date Received _____

TW/BWO Tube Type _____ Serial No. _____ Date Received _____

Date First Tested _____ Date Placed in Service _____ Date of Failure _____

Total Number of Hours of TWT/BWO Heater Operation _____

_____

1. Was operation normal just prior to failure? Yes _____ No _____
2. If not, what was done to adjust it? _____

_____

_____

3. Has proper cooling been maintained during tube operation? _____

_____

4. Did helix overcurrent tripout occur? _____

_____

5. Was environment normal? (specify) _____

_____

6. Symptoms - (describe failure) _____

_____

_____

7. Operating conditions at time of failure (indicate any unusual conditions) _____

_____

_____

8. Name of person to contact regarding evaluation of failure _____

Telephone No. _____ Signature _____

Title _____

Date _____

ALFRED

Tube Warranty and Replacement Procedure

TUBE REPLACEMENT

All TWT and BWO tubes furnished in ALFRED instruments are available from ALFRED ELECTRONICS for either warranty or out-of-warranty replacements. Current prices are given on the Replacement Tube Price List.

TUBE WARRANTY

The following warranties are applicable to tubes used in catalog instruments only. For the warranty applicable to tubes used or for use in special or modified instruments, please check with the factory. All tube warranties are from date of shipment by ALFRED.

WARRANTY FOR TWT AND VTM

Tubes are warranted unconditionally against defects in workmanship, materials, and construction within the period shown in Column A and the number of heater hours shown in Column B. To supplement the unconditional warranty, the tubes are warranted on a pro-rata basis for the rated number of heater hours shown in Column C or for one year, both computed from the date of original shipment by ALFRED, whichever expires first. The pro-rated adjustment will be based on the current list price of the tube and the unused percentage of heater hours (Column C) or one-year time period, whichever results in lesser credit.

Warranty Condition*	Tube Type	Applicable Tube Group or Alfred Tube Part No. Series	A Mo.	B Hours	C Hours
WC2	VTM	112-001 and 112-003	2	100	1000
WC3	TWT	10 and 20 mw output except WC4 tubes	12	500	2000
WC4	TWT	112-040 and 112-047	12	2000	-
WC5	TWT	1 watt output except WC6 and WC7 tubes	12	1500	-
WC6	TWT	112-046, 112-065, & 112-072	12	1000	-
WC7	TWT	112-057, 112-080, & 112-081	12	250	1000
WC8	TWT	2 to 10 watt output except WC9 tubes	12	75	500
WC9	TWT	112-055	2	50	500

* WC# denotes the corresponding warranty period(s) shown in the right-hand column(s) and is used for cross-reference to this warranty statement from other documents.

WARRANTY FOR ALL BWO TUBES

Tubes are warranted unconditionally against defects in workmanship, materials, and construction within the period shown below, without regard to the number of heater hours used.

Warranty Condition*	Tube Type	Warranty
WC10	BWO	Warranted unconditionally for one (1) year.

WARRANTY CONDITIONS APPLY ONLY TO TUBES LISTED ABOVE WHICH ARE USED IN ALFRED CATALOG INSTRUMENTS.

This warranty applies only to tubes sold after July 1, 1969.

TUBE SERVICE REPORT

TO OBTAIN WARRANTY CREDIT THE TUBE SERVICE REPORT MUST BE COMPLETED AND RETURNED WITH THE TUBE.

RETURN PROCEDURE

In case a tube or instrument fails, please contact the factory or your local sales representative for advice or authorization to return either the tube or the instrument to the factory. NO TUBE OR INSTRUMENT WILL BE ACCEPTED FOR REPAIR OR CREDIT ADJUSTMENT WITHOUT WRITTEN AUTHORIZATION AND ACCOMPANYING SERVICE REPORT.

When the authorization is received, pack the tube in a rigid container (use original carton if available) at least 4" larger than the tube in each dimension. Wrap the tube with 1/4" of soft padding material and heavy kraft paper before placing in container. Pack at least 2" of resilient dunnage such as rubberized hair, foam, or similar shock absorbing material completely around the tube. Mark the container "FRAGILE" and ship PREPAID via air freight, air express or rail express. Do not ship via parcel post or air parcel post since experience has shown that fragile items are more apt to be damaged when shipped via these methods.

Use similar wrapping, packing and shipping provisions for an instrument. At least 6" of rubberized hair (or equivalent shock absorbing material) is required for an instrument.

IN-WARRANTY FAILURE - BWO AND VTM TUBES

BWO and VTM tubes which fail in warranty will be replaced with a new tube. In case a tube fails, please issue a purchase order for a new tube at the tube list price and return the defective tube. Warranty credit will be issued and deducted from the price, subject to tube manufacturer's verification that failure was caused by tube malfunction. To qualify for maximum credit, it is essential that the defective tube be properly packed and returned within 30 days after failure.

REPAIRABLE OR IN-WARRANTY FAILURE - TW TUBES

If the returned tube is found to be repairable, the user will be asked to issue a purchase order for repair charges determined by the original tube manufacturer. In general, the repair will be at no cost if the tube is in warranty and there is no evidence of misuse or abnormal conditions of operation.

WARRANTY CREDIT

Any applicable credit allowed under the terms of this warranty applies only toward the purchase of a replacement tube from ALFRED ELECTRONICS. Cash settlements will not be made. In terms of this warranty, a replacement tube must be the same type as that on which credit is allowed. Credit for one tube only may be applied toward the purchase of a single replacement tube. Warranty credit remains in effect for a maximum of six (6) months from date ALFRED ELECTRONICS notifies the customer. All credits will be based on the purchase price of the tube which prevails at the time the order for a replacement tube is received by ALFRED ELECTRONICS.

BWO RF CABLES

RF OUTPUT CABLE MUST ACCOMPANY BWO TUBES returned for warranty credit, repair or replacement. If rf output cable is NOT returned, the cable price is added to the normal BWO repair or replacement charge. For prices see Replacement Tube Price List.

SPECIAL CONDITIONS

If a returned tube or instrument proves not to be defective after test and evaluation at ALFRED ELECTRONICS, the tube or instrument will be returned at the customer's expense.

The final determination as to whether the tube failed in normal operation thereby bringing it under the applicable warranty or whether the tube was misused thereby excluding it from application of the warranty provisions, lies solely with the tube manufacturer.

Data, warranty credit, and prices subject to change without notice.

8/1/69

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